PAPERS, REPORTS, DISCUSSIONS, AND MEMOIRS

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TECHNICAL SESSION

JANUARY 15, 1930—2:30 P. M. TO 5:30 P. M.

A PHILOSOPHY OF ENGINEERS' SALARIES

By Ernest P. Goodrich,* M. Am. Soc. C. E.

This is a presentation of the results of a study made by the writer of the basic factors which should be given consideration in determining engineers' salaries.

Social Development.—A study of the mechanism of Nature shows that sub-human life exploits other nature for food and shelter. Some ant-hills are veritable skyscrapers compared with the dimensions of their inhabitants. The beaver creates an artificial lake to protect his home. Some ants herd aphides like cows, while others make subterranean gardens for the raising of fungus just as men raise mushrooms in a cellar.

Man is therefore only following the schemes elsewhere adopted by Nature when he exploits other nature for food and protection against the elements, when he preempts land, burrows into the ground for its products, cuts down forests, raises herds, plants fields, and creates hoards of various commodities for future use.

Man, however, has gone farther in several ways. Very important items are the invention and operation of barter and exchange. In order to improve these activities, money was invented and bartering was changed to selling and buying. A further refinement was the payment for the temporary use (that is, rental) of land, of implements, and of credit.

Money rental, or interest, is payment for the use of capital, toward the hoarding of the physical original of which, time had been spent. Analysis shows that only an exceedingly small percentage of the cost of any commodity can be assigned as the measure of the exploitation of Nature's gifts by man. The rental of capital is thus only a small payment for time and labor spent in creating an equipment with which to work, and increases of salary at the expense of capital can only be exceedingly small.

The members of non-human societies appear to accept obligations toward the whole of their social groups. An obligation, from one point of view, is a duty. From the opposite aspect, it is a right. Whence probably evolved in the mind of man his so-called sense of right and wrong, and the whole field of ethics. Whence, also, evolved justice. Leadership and service are cardinal features of sub-human society as they should be of human groups. Human society seems more and more to be turning to the engineer for leadership in working out its salvation.

* *Chairman,* Special Committee on Engineering Employment in Public and Quasi-Public Service; Cons. Engr., New York, N. Y.

The Engineer's Expenses.—Even standards of living have been adopted by many varieties of animals. This standard is a variable quantity. Audré Siegfried says* the American workman's standard demands "a home, a bath, and a car for every family." Like the college teacher, for example, the engineer has three kinds of expenses to meet: The living expenses of himself and his family; savings (or their equivalent in pension guaranties) to assure economic security; and strictly professional expenditures like professional periodicals and books, society dues, expenses of attendance at professional meetings, professional tools and plant.

As to professional expenses, it seems pertinent to quote† certain advice given to young instructors:

"Make professional contacts, join the associations, attend meetings, read the journals, buy monographs, abstracts and books. * * * Devote at least 10% of income to professional development. * * * If you think you have ability, raise this allowance to 25% and gamble on your future. * * * Spend freely for professional needs in your earlier years, the proportion will be less later as you earn more."

A tentative list of budget items adapted to engineers in public service, would be as follows:

A.—Professional Needs:

(1) Membership in four or five professional societies costing from $10 to $25 up.
(2) Attendance upon one or two professional meetings costing from $50 up.
(3) Professional books costing $30 and up.
(4) Professional magazines costing from $10 to $25 and up.
(5) Travel for purposes of professional and cultural study, $100 or more.

B.—Economic Security:

(1) Retirement annuity, 5% of income with municipality contributing 5% more; and the annuities' reserve accumulation available in case of permanent disability or death before retirement.
(2) Life insurance costing 6 or 7% of salary to give a minimum protection of about three times the amount of salary; increased by term insurance during dependency of children and until annuity reserve accumulates; or increased by group life insurance costing 1½% of salary and giving life insurance equal to one's salary, plus disability and sickness insurance.
(3) Sickness and disability income provided:
    (*a*) By group insurance as just mentioned;
    (*b*) By a disability clause in one's regular life insurance policy;
    (*c*) By a special sickness and disability insurance.
(4) Provision against unusual emergency expenditures provided by an additional reserve fund either personal or pooled with others, about 5% cost of salary.

C.—Living Cost for Engineer and Family.

As far as known no comprehensive study has ever been made of the living costs of any large group of engineers as a class. What seems the nearest

* "America Comes of Age", p. 349.
† *Science*, July 12, 1929, p. 22.

comparable group as to which a recent study* has been made is a large section of the Faculty of Yale University.

Pensions.—A pension is a factor usually suggested to account for a common differential between pensionable employees and others. The present worth of a pension is the amount which otherwise would have to be invested annually to pay the premium on that pension. Such potential premium is the amount which a Government salary with a prospective pension may legitimately be less than a salary without pension prospect. Studies indicate that a pension prospect is really attractive only to men at least 40 years of age. Table 1 shows that Federal salaries might be considered fairly equivalent to non-Federal ones provided the Government employees are to be retired at the age of 55 with a pension equal to one-half the average salary for the previous five years.

TABLE 1.—THEORETICAL LEGITIMATE PERCENTAGE REDUCTION IN SALARY BASED ON PROSPECTIVE $4 000 PENSION STARTING AT RETIREMENT AT AGE OF 55 AND ACTUAL PERCENTAGE DIFFERENCES BETWEEN DEPARTMENTAL AND NON-GOVERNMENTAL AVERAGE SALARIES, 1928.

Age.	Equivalent salary reduction for $4 000 pension at one-half of last five years' salary ($8 000).	Assumed average salary for 5-year period, starting at stated age.	Equivalent total salary.	Percentage of actual to total salary.	Percentage of Governmental to non-governmental salary of nearest grade.*
20	$ 250	$2 000	$ 2 250	89	96
25	348	3 000	3 348	89	97
30	500	4 000	4 500	89	90
35	728	5 000	5 728	87	80
40	1 140	6 000	7 140	84	75
45	1 960	7 000	8 960	78	77
50	4 720	8 000	12 720	63	66

* Rept. of Personnel Classification Board, H. R. Doc. No. 602, 70th Cong., 2d Session, p. 82.

Effect of Cost of Living.—In the past many salary and wage commissions have devoted much attention to cost-of-living statistics and to the ratios between different years and different parts of the country. The annual cost-of-living curve is of value only in connection with determinations of changes in real wages based on past wage rates. These real wages and wage rates, however, have no possible connection with the fundamental principles of fixing salaries.

Geographical cost-of-living ratios may be of value in fixing one factor in the minimum grade salary. Assuming $900 as the annual living cost for an 18-year old man, these percentages for 32 cities (Table 2) correspond with a range from $724.50 to $1 033.20, a matter of $309, or nearly 43% of the lowest figure. It is obvious that the net result of taking account of the local cost of living is only to unify "real wages" throughout the United States, and thus to eliminate a certain amount of local differentiation.

* "Incomes and Living Costs of a University", by Henderson and Davis.

The question of the minimum salary is a very controversial one. Many students of the problem advocate absolute equality irrespective of the domestic condition of the payee. Others, like Douglas,* feel that,

"* * * as needs are not uniform, but variable, so the minimum wage should not be uniform, but should vary according to the needs of the worker and his family."

TABLE 2.—COST-OF-LIVING RATIOS.

City.	Index number.	City.	Index number.
Atlanta, Ga.	93.0	Mobile, Ala.	98.0
Baltimore, Md.	84.7	New Orleans, La.	91.8
Birmingham, Ala.	109.5	New York, N. Y.	108.0
Boston, Mass.	99.2	Norfolk, Va.	114.8†
Buffalo, N. Y.	103.5	Philadelphia, Pa.	104.5
Chicago, Ill.	104.5	Pittsburgh, Pa.	104.0
Cincinnati, Ohio.	80.5*	Portland, Me.	96.2
Cleveland, Ohio.	112.1	Portland, Ore.	100.0
Denver, Colo.	91.0	Richmond, Va.	93.8
Detroit, Mich.	109.0	St. Louis, Mo.	99.2
Houston, Tex.	98.0	San Francisco, Calif.	105.2
Indianapolis, Ind.	92.5	Savannah, Ga.	94.2
Jacksonville, Fla.	108.0	Scranton, Pa.	100.6
Kansas City, Mo.	92.1	Seattle, Wash.	109.2
Los Angeles, Calif.	100.8	Washington, D. C.	96.8
Memphis, Tenn.	107.0	United States.	100.0
Minneapolis, Minn.	96.0		

* Minimum at 19.5% below average.
† Maximum at 14.8% above average.

This practice of giving a family allowance is in operation in several European countries and has been widely discussed in Australia. While it is very difficult of operation in private industry (requiring mandatory legislation and enforcement), it is entirely practicable in public and quasi-public service, and is worthy of careful study.

A satisfactory answer to the cost-of-living factor can be derived only after very wide investigation. Such a study could be made by the engineers in each community in accordance with the specifications issued by the U. S. Department of Commerce, and be extended to the problem of family allowances by a wide compilation of engineers' family budgets.

Minimum Salary Based on Cost of Rearing.—Another direction of approach to the determination of the initial salary is through an estimate of the cost to society (generally to the parents of the individual) of bringing a man into this world and rearing and educating him up to the self-supporting age (Table 3).

For a man in the $2 500-income group, the cost up to the eighteenth year has been estimated† at approximately $10 000. The expectation of life at the age of 18 is 46.59 additional years. The annual payment required to amortize $10 000 in 46 years in equal annual payments, with interest on the unpaid balance accruing at 3½%, is $796. In addition, it may be assumed that the initial salary must include a figure to cover the cost of living.

* "Wages and the Family", by Paul Douglas, p. 41.
† *Statistical Bulletin*, Metropolitan Life Insurance Co., Vol. VII, May 1, 1926, No. 5.

Bases for Salary Determination.—Instead of starting at the bottom of the salary scale, it has been suggested that the pay of the engineering head be fixed on a proper basis.

TABLE 3.—FACTORS COMPRISING INITIAL SALARY, BASED ON COST OF LIVING PLUS AMORTIZATION OF COSTS OF REARING AND EDUCATION.

Economic group of family.	Total costs up to 18 years.	Annual payment to amortize total costs.	Cost of living.	Theoretical initial salary.
$2 500	$10 000	$ 796	$715	$1 511
5 000	20 000	1 592	900	2 492

The pay of the chief engineers (of highways) in forty-four of the States studied by Arthur Richards, M. Am. Soc. C. E. (a member of the Society's Special Committee on Engineering Employment in Public and Quasi-Public Offices), was compared with the following statistical facts:

(*a*) Population of State.
(*b*) Value of highway work done.
(*c*) Valuation of real estate in the State.
(*d*) Per capita U. S. taxes paid in the State.
(*e*) Total of U. S. taxes paid in the State.

This study indicated that the chief engineer's salary corresponds with the wealth of the State rather more closely than with any other factor of the amount of work done. The general indication is that the criterion as to salary is "what the traffic will bear". If this be true, the basis is illogical and unscientific.

Almost equally illogical, in that wealth (assessed valuation) is given considerable weight, is the law which determines the salaries of the county engineers in Ohio.

Comparative Salaries.—Data as to average salaries of engineers over a series of years are practically nil compared with the data which have been collected concerning workers in many other lines. In the diagram, earnings in teaching and the industries, as found by Mr. Paul Douglas, are compared with those of various groups of engineers.

That salaries in the public service tend to lag behind the changes which go on in society in general, is shown by the record of strikes and other public protests voiced by municipal employees in 1918, after the general price rise had become considerable, but before more than a start had been made in increasing municipal salaries.*

In 1926, the Society for the Promotion of Engineering Education published a report of a country-wide investigation of incomes of practicing engineers and of teachers of engineering. The results are summarized in Table 4.

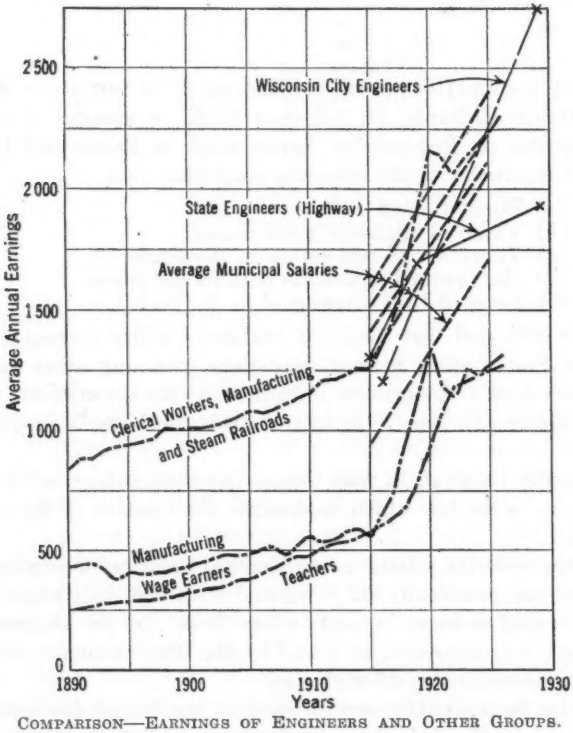
An analysis of the pay received by city and village officials in Wisconsin for the year 1929† shows that as to ten villages which have engineers, in nine

* *American City*, June, 1918, pp. 401 and 402.

† Municipal Information Bureau Reports Nos. 70–71, Univ. of Wisconsin, Univ. Extension Div.

out of this number the engineer was paid as much as, or more than, other village officials. As to forty-five cities, in fifteen the city engineer received as much as, or more than, any other official. For the year 1928, in the third-class cities of Pennsylvania* out of forty cases, the city engineer received a salary which was the highest paid to any official in twenty-seven instances. On the other hand, Professor Irving Fisher, of Yale University, is reported to have stated that the engineers (with an average pay less than $2 400 per year) were to be classed with the lowest paid group in the country:

"If we take the average for nine sets of union trades, we find that the average hourly rate increased slightly from $1.190 in 1927 to $1.195 in 1928."

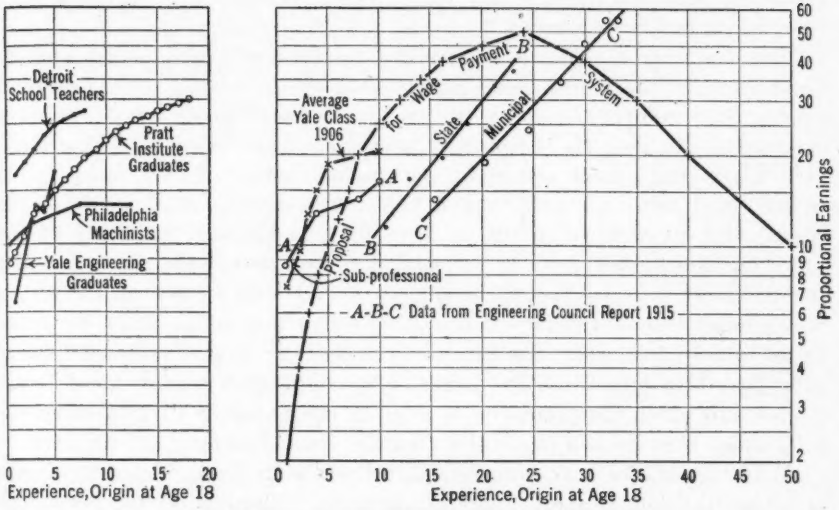


COMPARISON—EARNINGS OF ENGINEERS AND OTHER GROUPS.

If a 40-hour week and a 52-week year are assumed and if $1.20 per hour is employed, it is easy to estimate that a full-time year would provide $2 496 for a worker. With these figures may be compared the average salary paid to 275 engineers in the Bureau of Engineering of the Borough of Manhattan, New York City (according to the Civil List for the period, January-July, 1929) amounting to $2 797, or an average of $1.34 per hour, on the same basis of computation as before.

The proportionate salaries received by engineers of varying grade, as shown in the diagram, are found not to have varied materially either between

* Exhibit F, Rept. of Salary Survey Comm. to the Pennsylvania General Assembly.



RELATIONSHIP BETWEEN EXPERIENCE AND SALARY.

different services—Federal, State, municipal—or with passage of time during the past fifteen years, or with changes in classification, until that of the Personnel Classification Board is reached. The latter introduced one or more grades not theretofore recognized.

TABLE 4.—SALARIES OF ENGINEERS AND ENGINEERING TEACHERS.

Years after graduation.	Teachers' median.	Engineers' median.	Lower Limit of Engineers.	
			Highest 25%.	Highest 10%.
0	$1 500	$1 475	$1 500	$1 800
5	2 000	2 860	3 500	4 200
10	2 550	4 000	5 100	8 000
15	3 100	5 000	7 500	12 000
20	3 600	5 900	10 000	17 500
30	4 225	7 500	15 000	30 000

For some time, salary rates in many lines have been established on a longevity basis, presumably because years of activity bring corresponding experience and efficiency.

Engineering Experience and Probability.—There is such a close correlation between age and experience that it is difficult to determine with precision what part, if any, of a salary is proportional to an age factor, what to an experience factor, what to value of service, what to responsibility, and what to other factors.

While a Utopia with a different human psychology might operate efficiently with equal pay to each man for equal time spent, the present ideal of human justice accords a higher value to the time of the man who does the most to

produce a purchasable commodity which society values highly, at the specific time, place, and circumstance.

The investigators of the Personnel Classification Board as reported to Congress,* give the average rates paid to 5 652 employees in non-governmental employ, but grouped according to the grades established for Government employees. An analysis shows that the average pay varied as a function—very nearly the second power—of the grade number. Salary minus 2 100 equals (104) times the grade raised to the 2.25 power. An analysis of the compilation made by Richards of more than 12 000 men in all 48 of the State highway departments in the several States, shows that above the men in the lowest class (rodmen), the salaries vary closely in accordance with a very similar formula: Salary minus 1 500 equals a constant times the grade raised to the 2.78 power. The conclusion is clear, however, that present salary rates have been established by chance or by competition so that the different grades into which the profession is more or less naturally divided carry salaries which increase as a power (between the second and third) of the grade.

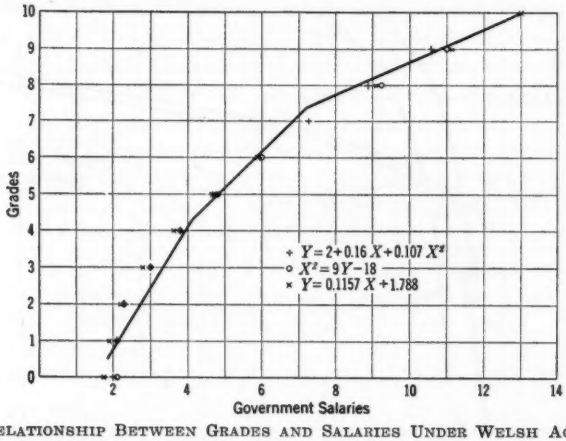
Why the salaries have been established where they are, if not by chance or by competition, is another interesting study. Plottings of the percentage distribution of the numbers of engineering employees in each of the studies mentioned against the respective salaries on Goodrich skew frequency paper gives substantially a straight line and shows that the salaries follow a law of frequency closely related to certain laws of chance. Plottings on double logarithmic paper reveal this law, which in the case of the engineers reported to the Personnel Classification Board is that the salary multiplied by (500 plus the number of employees who receive higher wages) raised to the 2.3 power equals a constant. This is somewhat analogous to what has been called the "demand curve" by certain economists when discussing the prices and quantities sold of different commodities. Buckwheat comes nearest to engineering as a commidity with a power of 1.80, according to investigations of the Cornell Agricultural Experiment Station experts.† Translated into economic language, the salaries of engineers are much less flexible than commodity prices. Again, engineers' salaries are much less affected by the distribution of the engineering population as to grade than are commodity prices with reference to variations in supply. The chart shows the relation of Government salaries and grades.

Age Distribution.—An analysis (Table 5) of the age distribution of the Civil Engineering Profession compared with that of the United States as it is, and as it would be were the population stable (without being affected by immigration or emigration), may possibly disclose one of the difficulties with reference to the salary problem. The figures for the youngest age group are sufficiently alike in all columns to indicate a normal situation. However, the percentages in the age group from 25 to 44, inclusive, show that a 50% larger number of practicing civil engineers are found in this group than would correspond with the average age distribution for the country under

* H. R. Doc. No. 602, 70th Cong., 2d Session, p. 82.

† *Bulletin 466*, March, 1928.

either a stable population or the actual one. The percentages for the higher age groups are in each case correspondingly less among practicing civil engineers so as to compensate for the excess in the 25-44 group.



RELATIONSHIP BETWEEN GRADES AND SALARIES UNDER WELSH ACT.

The falling off with advance in age, shows that a large number of practicing civil engineers among the younger age groups must leave the profession. One of the reasons may possibly be inadequate compensation. The 50% larger ratio compared with the whole population of the country shows that the supply is probably in excess of a normal demand. If this is the case, it explains the depressed condition of the salaries in the lower age groups. That there is little prospect of any material change in this problem of age distribution (if the past is any criterion), is shown by studies made by the Metropolitan Life Insurance Company.

TABLE 5.—PERCENTAGE AGE DISTRIBUTION, TWENTY YEARS AND OLDER.

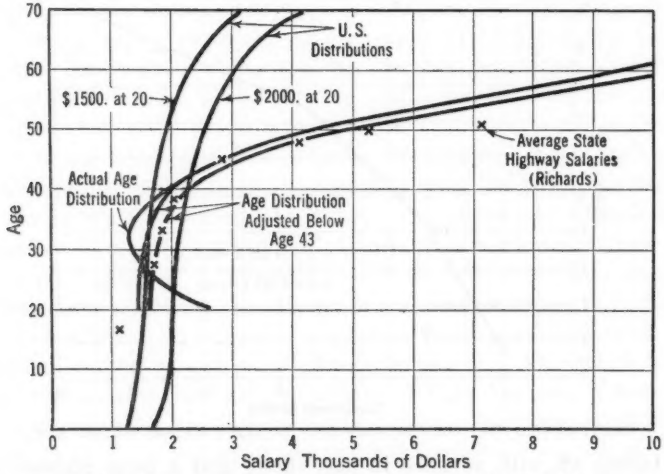
Age group.	Stable population.	United States population.	Civil engineers.
20–24	11.5	14.1	12.3
25–44	42.5	49.8	64.3
45–64	32.5	28.3	19.3
65–up	13.5	7.8	3.5
20–up	100.0	100.0	100.0

Supply and Demand.—If the law of supply and demand were the only condition fixing salaries, and if the so-called "demand law" is assumed as,

$$N S = K$$

in which, N is the number available at any specific age, as found in a life table, S is the corresponding salary, and K is a constant depending upon the assumed salary at any given age, then the salary at any other age can be computed, as shown in the diagram.

If the actual distribution of civil engineers is employed, obviously the earliest age group would receive higher salaries than the group from 25 to 40 years.



RELATIONSHIP BETWEEN SALARY AND AGE BY $N S = K$ LAW.

If the salary is based on an adjusted age distribution curve below 43 years, such that the same total number of competitors is found with the later ages redistributed to earlier years (similar to the United States age distribution), a salary distribution results like that shown in Columns (6) and (7) of Table 6.

TABLE 6.—SALARIES BASED ON VARIOUS ACTUAL AND ADJUSTED AGE DISTRIBUTIONS.

Age.	UNITED STATES AGE DISTRIBUTION.				CIVIL ENGINEERS' AGE DISTRIBUTION.	
	Number of competitors, percentage.	Salary For:			Actual.	Adjusted below age of 43.*
		$1 500 at age of 20.	$2 000 at age of 20.	$5 000 at age of 50.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
00	100	$1 260	$1 680	$3 300	.....	.....
10	87	1 450	1 930	3 800	.....	.....
20	84	1 500	2 000	3 940	$2 640	$1 630
25	....	.....	.....	.....	1 870	1 670
30	80	1 580	2 100	4 120	1 350	1 750
35	....	.....	.....	.....	1 390	1 900
40	74	1 710	2 270	4 450	1 940	2 180
45	....	.....	.....	.....	2 860	3 160
50	66	1 910	2 540	5 000	4 300	4 750
55	....	.....	.....	.....	6 450	7 100
60	57	2 220	2 950	5 800	9 360	10 400
65	....	.....	.....	.....	14 700	16 300
70	40	3 150	4 190	8 260	25 800	28 400
75	....	.....	.....	.....	.....	.....
80	16	7 900	10 500	20 700	.....	.....

* Typical scale adjusted to rate for highway engineers, $1 865 (computed by Richards) for first professional grade.

By using the age data for different grades secured by the Engineering Council Committee, a somewhat different series of studies and curves is developed.

The correlation is then surprisingly good except at the two ends. In order to procure a correspondence there, it would be necessary to give the readjusted age distribution curve a sudden and violent upward tilt from 20 to 17 years. It would also be necessary to drop the curve at and beyond 50 years in a manner quite contrary to age facts.

In other words, while the law of supply and demand seems to have considerable influence in determining salaries, it is seen not to apply at the upper end of the scale and over the whole of the lower half of the age period.

Avenues of Further Effort.—Several possible lines of action are suggested by these studies. The attention of professors of civil engineering could be drawn to the anomalous age condition and they in turn could transmit the information to the lower classes in the engineering universities. The authorities in such institutions could be advised to make the requirements for graduation much more rigid so as to reduce the number of graduates who attempt to enter the profession, and who must compete with non-graduates and with well-qualified graduates of foreign engineering schools. Finally, the Engineering Societies could become active in establishing a rigid licensing law in every State and in advocating, at all times, compliance with stringent requirements before permitting a man to practice.*

Returning to the supply and demand curve, it is possible that the explanation may be that the numbers of men of proper quality are not available. Table 7 gives the results of intelligence tests given during the World War on possibly 250 white engineer officers analyzed according to age groups.†

TABLE 7.—Table of Intelligence Tests by Age Groups.

Age.	Median score.	Standard deviation.
21–25	325.7	24.2
26–30	325.0	31.8
31–35	299.4	38.5
36–60	280.0	....

After estimating the probable standard deviation for the 36 to 60-year group, it is possible to determine with fair success the relative possibility of securing a man in any age group of a given or better intelligence score. For instance, using diagrams not here shown, it is found that, if a man of median intelligence in the oldest age group is considered, 50 out of each 100 men would qualify. For the same intelligence score among the men in the next lower age group, 70 men out of 100 could qualify, with about 80 and 90 in each still lower group, respectively. Or, if a man of upper quartile intelligence in the oldest group is desired, then only 25 out of 100 will qualify, while in the several lower groups, the numbers will be 40, 50, and 50, respectively. This

* See, also, "Professional and Business Ethics", by Taensch, p. 230.

† See *Memoirs*, National Academy of Science, Vol. XV.

reduction in the intelligence score with age, and the resultant relationship of high intelligence to the upper age group possibly explains the increase of salary with increased grade at a greater rate than the simple age-group reduction in size.

If, however, an intelligence rating of 280 is selected for all grades, then a scale is produced which is surprisingly close to salaries actually received as shown in Table 8.

TABLE 8.—COMPUTED PROPORTIONS OF EACH AGE GROUP WHICH CAN EXCEED A RATING OF 280, INTELLIGENCE SCORE, AND CORRESPONDING SALARY SCALE.

Grade.	Age.	Percentage of group with more than 280 score.	Typical salary scale.	Highway salary (Richards).
1	17	80	$1 290	$1 141
2	22	88	1 230	1 600
3	28	84	1 340	1 729
1	33½	72	1 865	1 865
2	38½	64	2 080	2 077
3	42½	55	2 900	2 695
4	45½	50	4 170	2 800
5	48	49	4 700	4 112
6	50	48	6 250	5 295
7	51	48	6 800	7 108

That there is some correlation between intelligence and compensation is evident from the intelligence curves for such Army groups as enlisted men, non-commissioned officers, officers in training, and officers. These studies lead to the suggestion that some professional psychologist be interested in devising a test specially adapted to grading the Civil Engineering Profession to be used in connection with the efficiency ratings hereafter discussed.

Public Recognition.—It is trite to review to engineers the conquests of engineering, or to try to demonstrate to them their value to society. It is only when the public understands and appreciates these facts that the engineer will receive monetary appreciation as well as public praise.

It is the engineer in the service of the public who has made and is making, at least in great part, what is called progress, and who has advanced civilization; but it is felt that much less public recognition has generally been accorded him than he has merited. As one prominent administrator has suggested,* the civil engineer, at least, has fostered an inferiority complex.

Before the days of the monopolistic trade union which has somewhat upset the general conclusions of the classical economists, those estimable gentlemen would have said it was the law of supply and demand which determined the pay of the worker just as it did the price of other commodities.

But that heartless economic law has been upset in the past by various methods on numerous occasions. Trade unions among engineers have been formed, but have been frowned upon by other engineers, other professional men, and by the public. When a mild threat was presented to the Mayor of New York of such a step, he retaliated by a threat of a lock-out. Generally

* *Proceedings*, Am. Soc. C. E., May, 1928, Pt. 2.

speaking, not enough votes are ever involved to give the threat weight with the politician. The only alternative would seem to be an effective appeal to fair play (most politicians are sports), or to arouse sufficient (and it must be a very large amount) public opinion as to the justice of the plea of the engineer in the public service for greater compensation.

Various Solutions of Wage Problem.—Comparison of pay between different classes and professions can become justifiable only when a value can be placed upon the services to the public of each such class and profession separately. To prove by income tax reports or otherwise that the young engineer gets more pay than the young lawyer, or that all engineers average the same as all physicians and as all lawyers may show only that all the professions are under-paid, in the absence of some independent valuation of the services rendered by the several professions.

Adam Smith and his disciples discussed at length the law of supply and demand; that human labor is a market commodity, that the economic motive is a primary incentive which attracts or (when the reward is not deemed sufficient) fails to attract,* with "enlightened self-interest" dictating increases when strikes and other clouds portend.

The latest school of thinkers tends to treat the whole wage problem as one fundamentally of ethics. Society functions best and progresses most when justice is done between man and man, in accordance with the collective moral ideas of what is right, fair, and proper. According to certain historians, civilization decays when justice fails.

If it proved anything, the World War proved that might did not make right in human affairs. A higher ethics is becoming operative and the simple plea of simple justice is often the most powerful method of overcoming injustice when such a condition can be shown to exist. President Harding discussed social justice and advocated for the worker what has come to be known as a "saving wage".

Still later, the productivity theory of wage payments became prominent. In other words, a man's earnings should be measured by his productivity. By this thesis, salaries should be based on a scale of stipulated accomplishment. A scheme must also be included for ascertaining how far above or below the specification, a man's work actually rates. Such a system has been applied in various organizations, and one is described in "The Survey."†

While psychologists have differentiated a conservative type of mind which prefers certainty to chance of increase, and while most engineers (particularly the older ones) in public and quasi-public service are generally accredited to that group, it would be much more to their economic benefit if such engineers were forced into a system of payment for performance, or payment for production.

The fixed salary is generally considered derogatory to the best interests of the recipients.

With increased production, a claim for salary increases would be only justice. Obviously, such salary raises must be such as to take only a proper

* "City Engineering Jobs Go Begging", *New York Times*, September 22, 1928.

† April 20, 1912, pp. 125 and 126.

portion of the savings, so as still to lower costs. Henry Ford states* "Wages are not in the discretion of the employer, but in the productivity of the business."

Sometimes engineers should intervene on their own behalf (through representatives of the engineering societies). A few years ago claims were made by the Railroad Brotherhoods and the Railway Companies in turn for the savings from increased operating efficiency.

In none of the extended arguments, as far as known, was any reference made to the work of the engineers, who conceived, planned, estimated, designed, constructed, and controlled the operation of these relatively labor-reducing and profit-increasing efficiency measures. Simple justice would dictate at least a quarter division for each of the parties at interest, namely, the capitalists, operators, engineers, and public.

Public Interest.—If a plea for simple justice fails based on these general arguments, then resort can be made to the motive of "enlightened self-interest". Human psychology is such that poorly paid employees become discontented, and unintentional or intentional sabotage is the result. While certain types of political psychology would see a gain in this result because it would make more positions necessary—the enlightened self-interest of society dictates higher wages because the output has been found to be in even higher proportion. Enlightened self-interest and justice are here seen to be synonymous, at least in result. Probably they are also fundamentally synonymous since justice is that which is generally acknowledged to be "right", and right is that which has been found from the experience of the ages to be "best" for, that is, desired by the largest part of, society; and, finally, "best" is in essence what gives most assurance of a perpetuation of society under conditions which are esteemed by it.

Since the "product" of civil engineering activity is service, the evaluation of the product is in reality a valuing of the service rendered.

Determining Salary Scales.—The time is now believed to have arrived when engineers' pay should be placed more nearly on a par with the value of the service rendered, or in proper proportion thereto. An acceptable measure of value must first be determined. Since engineering service is fundamentally team-work (except possibly in the cases of the consulting engineer or the expert witness), this measure can best apply to a group, to a whole engineering organization, and the distribution within the group can then be made on the basis of relative responsibility, of technical skill employed, and of other factors. Such a differentiation within a group has been suggested and to some extent practiced in machine-shop wage establishment.

The pay of the lowest sub-professional group having been established, the rates for other grades in the various types of organization—small and large cities, counties, States—may be then evaluated as multiples of it. The extent and character of the work of an organization will then expand or contract the over-all spread of the scale—the chief engineer of a small county road project hardly being expected to receive as large a salary as would the

* *New York Evening Post*, November 11, 1929.

chief engineer of a large subaqueous railroad tunnel, for instance. Finally, the whole scale as thus scheduled should be so applied to the organization throughout its estimated life, as to provide a compensation for that organization commensurate with the value of its services to society.

Criterion for Gross Engineering Cost.—And what is the value of engineering service? A tunnel will save distance and probably rise and fall for the traffic which will use it. These effects can be given a monetary value. A bridge has similar economic results. A new real estate development will enhance land values to the land owner. Maintenance of pavements saves tire wear and spring breakage, reduces time of vehicles in transit, and often enhances property values.

In the transportation field, it has been found that an increase of rates, other things being equal, reduces the traffic. The total amount which can be paid in salaries and wages for all employees is thus shown to be established at some fraction (variable to some extent with the cost of money and of the materials which are required for maintenance) of that maximum income which can be secured at the optimum fare. Within the transportation industry the wages of the various trades and callings must be so adjusted as to total this maximum figure and as between trades must bear relationships which correspond with the varying degrees of skill, training, responsibility, and experience required.

On all jobs which are substantially repetitions of old designs, the relationship between professionally planned and executed projects and those executed by laymen should be the criterion for the professional pay. As between professional jobs, extra compensation should be given whenever special construction or operating savings can be demonstrated.

It is not to be understood that each job is to have the compensation so computed, but that gross engineering professional work should be measured by this criterion. It puts the profession on its metal to show initiative, to do the best work for the least construction cost (not the way much Government work is apparently done—without regard to cost—or with no reference to the tax-payers' pocket-book), and so that management and operation may be more efficient. Conversely, it will show the public wherein and to what extent the Engineering Profession is of value to society. But it will be asked, how is the rate to be determined of the routine designer and constructor of standard structures, such as re-pavements, typical railroad structures, or warehouses, wharves, and piers? A pure copyist deserves a copyist's pay as determined by the law of supply and demand, but no real engineer is content merely to copy. He tries to improve, to reduce costs (at least relatively), to save his clients money by introducing new materials and methods. For these, he should receive proper reward. It is trite to repeat that nothing is so perfect to-day but that it may be improved.

Subdivision of Gross Cost.—With the gross pay assumed thus to have been determined, the sole question is as to the distribution which should go to the personnel. All engineers will agree that demonstrated ability, experience, responsibility carried, effectiveness of doing one's job, are items which deserve compensation. Perhaps some, but only slight, consideration should be given

to potential ability, disclosed but not actively utilized. Similarly, experience acquired but not actually utilized deserves only "stand-by charge" type of compensation. Again, potential and actual responsibility need differentiation, while the effectiveness with which a man meets his clients, his associates, assistants, and the public, is deserving of proportional reward, irrespective of ability or experience.

There is thus seen to be a large personal equation which deserves commensurate consideration. In a small group where each man is known to all the others, these personal factors can be rewarded even though a man may thus receive pay out of proportion to the position which he would occupy in a large organization where pay must be proportional to the position rather more than to the individual. Under the latter conditions, an able, energetic, effective man should receive his reward by rapid promotion and that seems to be the best method of compensating him even though such reward be usually somewhat deferred compared with the theoretical possibilities of advancing his salary while in a given job.

The problem seems next to resolve itself into a determination by the profession among its members of the proportional pay which is deserved by jobs of varying complexity and responsibility, as fixed more or less arbitrarily by carefully formulated specifications. After the creation of such job specifications, the present average proportional pay for each can be computed from present practice.

In order to complete the picture and connect the individual compensation with the total which should be paid for professional service on any project, or in any large organization, the numbers in each grade must be determined.

Theoretical formulas afford data for computing many varieties of problems, but in the long run, organization experience will dictate the numbers in each grade to meet each specific case. In fact, the number of grades found necessary and their specifications will differ widely in county and in Federal service, for example.

Efficiency Ratings.—At one time there was a great vogue for self-analysis, and "ask me another" books were "best sellers". Why not apply that same method in a quarterly analysis of one's own efficiency?

A second alternative is to have each member of an organization rate quarterly all those in the same grade, and in those immediately above and below him, so far as his knowledge goes. These ratings should then be averaged by some outside accountant's assistant.

A third alternative is the establishment of an efficiency system in each office and organization, which will evaluate periodically each man's work. In one such system, each man was rated as a percentage of the average score, and the average was weighed according to the amount of work turned out by the whole office each quarter.

Each one of these alternatives can be operated unofficially at the start and when their worth has been demonstrated, they can easily be made official.

The value of any such system with data taken before and after a salary increase would be of inestimable value both to the engineers themselves and to their paymasters—the general public.

Let each engineer in each organization—either individually or in groups—in student and local chapters, by self-constituted or formally appointed committees, throughout the whole country and the world, undertake thus to value the work which his organization is doing for society and how efficiently it is being done in every line of civil engineering endeavor. Let these matters be discussed in private and public, let them be published to secure the reaction of the public; let them all be sent to the Secretary of the Society for the benefit of this and future committees on public and quasi-public service salaries.

Public Funds for Increased Salaries.—Next, how are engineers to find the money with which to pay for their desired increases in compensation? Most engineering projects are financed by capital issues—bonds and stocks. Where the method of financing is by means of direct taxes or assessments the device hereafter suggested must be slightly modified.

Assume that the engineering costs of a project aggregate 10% and that the engineering compensation is to be doubled. This means that 10% more bonds must be sold. Now it is very easy to compute the extra length of life of the bonds required to cover this extra item on the assumption that no greater sum is set aside annually for interest and sinking-fund appropriations than would be the case under the original salary scale. If the bonds are given this extra life, the immediate tax burden is not increased by one dollar. The annual appropriation for interest is increased at the expense of the annual sinking-fund contribution. To be sure, the tax-payers will be paying over a greater number of years, but they are only paying what is justly due and at a time when they would otherwise be securing the benefits of the improvement project with absolutely no cost of financing. Theoretically, it would be entirely just for them to pay the interest charge forever, as a rental value of the improvement. That is what is done in the case of private land ownership and for the benefits of permanent improvements financed by private capital.

Computations show that a $1 000 000 improvement financed by bonds carrying 5% interest, with a sinking fund amortized at a rate of 3½%, to which an additional 10% is added for increased engineering compensation, will have to be extended by 3.86 years if the original life was fixed at 20 years, and by 14.44 years if the original life was to have been 40 years.

In the case of improvements paid by direct assessment, the increased engineering salary will not be deserved unless it can be shown that it has been earned from the increases in values created. In the case of positions paid from taxation, the appeal is one to the tax-payer (who can logically be the only objector) on the basis of the modern theory that high wages provide enlarged purchasing power. In most communities the largest tax-payers are the merchants and manufacturers who will benefit directly by any increased consumption. In other words, they will get back the money paid through taxes in increased salaries from increased spending. Henry Ford is the great, and a very successful, exponent of this principle.

After a scientific schedule of rates of pay for engineers is established, it should be made widely public. It should then be broadcast that tender of

less pay than the schedule calls for, indicates willingness to accept an inferior quality of work; while acceptance by an engineer of sub-scheduled pay is an acknowledgment of less than the required professional ability.

The Solution in a Nutshell.—To resume:

1.—Make a comprehensive cost-of-living survey of the country, together with a compilation of 100 000 engineers' family budgets.

2.—Reduce the numbers who join the profession annually by more rigid college requirements and by forceful registration acts.

3.—Compute the money value in as many instances as possible of the value of engineering service. Send this information to the Secretary of the Society. Get it into the local newspapers. Talk about it before local clubs, associations, and tax-payers' groups.

4.—Study how to increase efficiency and engineering productivity and to improve the management of all engineering activities so that the tax-payer and society in general will receive something worth increased pay.

5.—Show budget makers how to increase salaries without increasing the apparent tax burden and where increased productivity and efficiency are possible with a financial incentive to maintain it.

* 6.—Study the social economics of increased consuming power with increased pay and talk this Ford principle on all appropriate occasions.

7.—Educate the professors of engineering in all the colleges to these ideas and see that they pass them on to their students so that in the course of a few years the newly pledged engineers will earn and press for better pay.

It may be concluded that the Engineering Profession has a mighty opportunity to create a civilization as much more brilliant than the high point of Athenian or mediæval life as that was above primitive social standards. The engineer was accused of having made the World War. It was he, too, who was really the instrument which ended it. It is he who can plan for and effectuate political tranquillity by the same means, and can increase the security on capital invested in industry and transportation. The resultant will be a decrease in the rate of rental on capital, an increase in the wage of labor, both manual and mental, which in its turn will increase consumption, raise progressively the living standard, provide more leisure time, give opportunity to increase art and culture, and raise civilization accordingly. Moreover, besides his consciousness of well-doing, the engineer can and, it is believed, will be paid accordingly.

STATUS AND PROGRESS IN THE ART OF HIGHWAY ENGINEERING

REPORT FOR THE HIGHWAY DIVISION

By Henry B. Drowne,* M. Am. Soc. C. E.

The United States Bureau of Public Roads reports that in the year 1928 a total of 29 252 miles of highways were improved by the forty-eight States. At the end of the year the State systems comprised a total of 306 442 miles of the following types:

	Miles.
Sheet asphalt	1 498
Brick and block pavement	3 326
Bituminous concrete	5 392
Sand clay and top-soil	13 499
Bituminous macadam	15 200
Water-bound macadam	18 142
Graded and drained highways	31 755
Cement concrete	42 957
Gravel	93 124
Unimproved highways	81 549

Since the presentation of the previous (1928) report† of the Executive Committee there has been no marked change in the methods of construction of the different types of pavement which were outlined in that report. Believing that a brief review of the design trends, the application of recent developments in highway research to highway construction, and the development of equipment used in the art are of extreme interest, these subjects have been incorporated in this report. Some repetition of matter included in the 1928 report is unavoidable, but it will emphasize the trend mentioned last year, which certain features of the art are taking.

Design Trends

Preserving Natural Beauty.—One of the outstanding developments in highway engineering during 1929 has been the growing appreciation on the part of the highway engineer of the esthetic phase of his work and the definite improvement that may be made by choosing road locations so as to bring out the natural beauty of the locality. It is no longer sufficient that highways be wide and smooth; they must also be pleasing to the eye. To this end the new designs show more wide-sweeping curves; increased use of short tunnels and half-tunnel sections in mountainous locations where it was formerly the practice to blast away the picturesque cliffs; more intelligent study in the preliminary clearing operations so as to preserve the specimen trees and develop vistas of outstanding beauty; and more careful design of bridges and culverts to harmonize with the general character of the landscape.

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† *Proceedings*, Am. Soc. C. E., March, 1929, Papers and Discussions, p. 581.

The growing appreciation of natural beauty on the part of the general public has resulted in legislation against disfiguration of the highways by unsightly signboards, shacks, lunch stands, etc. All but seven States now have some kind of regulations governing highway advertising, and in these seven States there are city and county regulations or a certain degree of control vested in the State highway departments. Considerable progress has been made in the beautification of highways by plantings of native trees, shrubs, vines, and flowers. The work along this line being done by the Connecticut, Massachusetts, and California Highway Departments is especially commendable.

Embankment Settlement.—More attention than formerly is being paid to constructing the road grade. Earth embankments put up by different methods do not settle in a uniform manner, and engineers are realizing that satisfactory results cannot always be expected from fills loosely thrown into place and left for Nature to consolidate. As a result of the use of modern road-grading machinery, the road embankments now being built are generally less stable than those constructed under the older methods which required thinner layers and more hauling over the fill. Compaction of the fills by the layer method or by water settlement (ponding or jetting) are two methods now being used successfully. There is an obvious lack of data on the subject of fill settlement, and research work on this phase of highway improvement is needed.

Sub-Grade Studies.—More progress has been made during the past year in soil classification and sub-grade investigation than in any similar period since this important phase of highway work was undertaken. Through the impetus given this subject by Charles Terzaghi, M. Am. Soc. C. E., and the detailed studies and articles by C. A. Hogentogler, Assoc. M. Am. Soc. C. E., the problem has been simplified and classified so that for the first time a classification of soil characteristics has been developed that is understandable and usable by the average field engineer. This classification throws the sub-grade soils into eleven groups, eight for uniform, and three for non-uniform, sub-grade materials. With further research and the simplification of the soil analyses in the field, it is expected that consideration of sub-grade characteristics will become more common practice in all highway work.

Curves.—There has been a continued upward trend toward better standards of grade and alignment during 1929. Several States are now using curves of 1 000-ft. radius as standard design, but most States have not found it feasible to adopt this length of curve. Except in mountainous country, however, curves of less than 500-ft. radius are soldem used. On account of the increased speed of motor vehicles, unobstructed sight distances at both horizontal and vertical curves are very important. On main highways a clear sight distance of at least 500 ft. is now the usual requirement.

Superelevation of curves has become standard practice, but the amount of such superelevation and the method of developing it vary somewhat in different States. In general, the recommendation of the American Association State

Highway Officials is being followed, that is, a maximum superelevation of 1 in. per ft. of width, based on the formula,

$$E = 0.067 \frac{V^2}{R}$$

in which, E is the superelevation, in feet per foot of road width; V, the velocity, in miles per hour (35 recommended); and, R, the radius of the curve, in feet.

Widening of curves is practiced by most States, but this feature is becoming less important due to the fact that the curves are much flatter than formerly and hence widening is less necessary. In one State where flat curves are standard practice, widening has been discontinued except in mountainous locations. Due to so much fast night driving, the use of reverse and compound curves is giving way to simple curves separated by tangents of considerable length except where the radii of the curves are so large as to have the effect of sections of tangents.

Grades.—On main-line highways, 7% grades are commonly the maximum permitted, but in rugged country it is not uncommon to find the use of 9% grades rather than the introduction of sharp curvature. Where the grade is more than 5% on a curve of less than 500 ft. radius, it is common practice to compensate the grade to permit unretarded ascending speed.

Width.—With the increase in speed of motor vehicles, especially trucks and buses, the safe width of traffic lane has been increased and is now commonly considered 10 ft., although many States still build 18-ft. pavements for two-way traffic. Highways of four, six, and eight lanes are being built adjacent to large cities, but some engineers prefer to construct several independent two-lane roads instead of one multi-lane super-highway.

Crown.—On hard surface pavements the amount of crown is now very slight, $\frac{1}{8}$ to $\frac{1}{10}$ in. per ft. being the prevailing practice. The requirements for surface trueness now commonly practiced permit this flattening of the transverse profile.

Shoulders.—Due to the congestion and danger caused by cars parked on the pavement, provision is being made for emergency repairs and general parking by constructing shoulders 6, 8, and 10 ft. in width. Many States are finding it beneficial to keep a good sod on the shoulders to prevent excess washing during heavy rains and floods.

Railroad Grade Crossings.—Railroad grade crossings continue to receive attention and several hundred have been eliminated during the past year. Wide differences of opinion exist between the railroads, public service commissions, and State highway departments relative to the program of elimination and the method of dividing the expense.

Highway Grade Separations.—Separation of grades and the protection of traffic at highway crossings has received more thought during 1929 than ever before. The separation of grades with provision for right and left connections between the routes appears to be the design most generally acceptable, but this is expensive construction and has not yet been used extensively. Where highway intersections are at grade several methods are being used to safeguard

traffic. During the past year the widening of the pavement at intersections has gained in favor and seems to be best adapted to the automatic signal light that is coming into use at important rural intersections.

Guard-Rails.—Light wooden guard-rails are no longer considered proper protection for modern traffic and have given way to heavy hub-high wooden guard-rails, woven cable, or flexible metal rail types. Boulder guard-rails and earth banks are being used with success in some States.

Road Types.—During 1929 considerable progress has been made in the art of bituminous treatment of gravel and sand clay roads. Experiments in the East have been confined mostly to the surface application methods, whereas in the Western States oil processing (combining road materials in place with oil) has received the most attention. Various experiments have been conducted with asphalt emulsions for surface treatments and for processing as well as for macadam and bituminous concrete.

Several States have experimented with thin-layer traffic-bound surfacings with apparent success. These surfacings are built up gradually by applying a thin layer of fine crushed rock, gravel, or slag to the sub-grade and as traffic compacts this, other thin layers are added until a compacted crust 6 or 8 in. thick is produced which later may be bituminous surface-treated or used as a base for a bituminous macadam or bituminous concrete pavement.

In the gumbo soil sections of the Northern Mississippi Valley States many miles of clay sub-grade have been treated with asphaltic oil and gravel blotter with apparent success. In bituminous concrete construction there has been some experimentation with cold asphalts and cold tars similar to the popular English practice; but whether the cold-laid types will gain the same popularity in this country remains to be seen.

The use of the finishing machine for bituminous concretes has progressed during the past year and appears to be generally more satisfactory than hand-finishing methods. The design of bituminous concrete mixtures has been improved by the use of two tests, namely, the stability test of Hubbard and Field and the shear test of the Chicago Paving Laboratory. The practical value of these two tests has been demonstrated. Results of the laboratory investigations and construction agree so that the design of mixtures may be determined on a scientific basis.

In cement concrete pavement construction considerable progress has been made during the past year in the control of aggregates and in methods of curing and finishing. The volumetric proportioning of aggregates is no longer considered sufficiently accurate control, and proportioning by weight is becoming standard practice. Progress has also been made in the scientific grading of coarse aggregates by separating the sizes and re-combining in proportions which will produce the maximum practicable density. Machine-finishing methods have practically superseded hand methods except on very small jobs and the tamping screed is now very generally omitted. The use of bituminous material for curing concrete pavements has increased remarkably, but whether this trend is a permanent one remains to be seen. The use of sodium silicate and calcium chloride has also increased considerably.

Traffic Control.—Pavement marking has become very common practice in the control of traffic. White bands 6 in. wide painted on the road surface around curves and at hill summits are very effective. The American Association of State Highway Officials has standardized warning and direction signs and gathered this information together in the form of a manual. The boulevard stop system which requires the stopping of all vehicles before entering a heavy traffic main route is a method that may be used to advantage at some points of danger.

The use of automatic signal lights of the "stop-and-go" type at intersections of intercity roads is questionable unless the traffic in both directions is of about equal intensity. It is the opinion of the National Highway Research Board that the loss of time and inconvenience caused to through traffic by its necessary passage through congested areas far exceeds any local convenience or benefit accruing to the community by having the traffic so routed.

The planning of traffic handling is an engineering problem upon which research engineers have not as yet impressed themselves. Development thus far has come about through observation and experience and the interchange of opinions. There is a real need for research that will divorce itself from present regulations and conditions and develop the fundamental mechanical and psychological principles upon which regulations that will expedite traffic movement with safety can be based. Practice in regulating traffic should be based upon substantiating data, such as can only be procured through painstaking research.

Application of Recent Developments in Highway Research to Highway Construction

The application of the results of research work of necessity lags behind the pronouncement of new information by the research workers. Also the effects of research upon construction practice come about slowly through partial adoption of new principles, and through the gradual spread of new ideas. It is difficult to say that within any one-year period, new methods have been devised and brought into general use, but a few years' retrospect shows that research is having a profound effect upon highway engineering practice.

Some of the more notable tendencies will be mentioned and also some of the important features in which research information is lacking.

Foundations and Drainage.—Thus far, engineering practice has not been greatly modified by the extensive scientific inquiry into soil behavior and soil mechanics, but recently attempts to correlate these researches with highway engineering results have been developing rapidly. The efforts of the men working in this field are culminating in practical understanding of the interrelationships between sub-grades, surfaces, traffic weights, climate, etc. In time the result will be manifested in greater durability.

Through twenty years of research, sound theories for the determination of external loads on closed conduits have been developed to the point where rational design of highway culverts is easy and practicable.

Earth Roads.—Little progress on the most important problem—that of making these roads usable throughout the year—has been made. "What is

needed is the development of some now unknown method of soil treatment that will result in effective and very low cost improvement of the thousands of miles of earth roads." There is probably no other single investigation that can be defined that is of as much importance in the highway research field.

Intermediate Type Roads.—Many different types of such roads have been built on an experimental basis and fortunately most of them have been carefully described in publications of wide circulation. A definite use of this information is noticeable as the reports of the newest projects appear.

There is a real need for thorough technical study of the fundamental effects of the different characteristics of bituminous materials and mineral aggregates upon the results secured by mixtures used in road work. From an economic standpoint, the need of data on the effects of increasing traffic on maintenance costs for these roads is a pressing research problem.

Asphaltic Pavements.—The development of the stability test for bituminous mixtures with fine aggregate is having important effects in meeting the new conditions put upon these pavements by the increase in motor-vehicle traffic. There appears to be a need for the application of stability studies to coarse aggregate mixtures.

Concrete Pavements.—By this time the principles of design developed by the "Bates Road Tests" have come into very general use. Refinements based on research are being made. The more recent developments have to do with methods for control of concrete mixtures to produce uniform concrete of predetermined strength and with economical use of available materials. The use of designed mixtures, weighing of aggregates, corrections for moisture condition of aggregates, and accurate water-measuring methods is spreading rapidly. Further developments along this line are retarded pending the finding of a satisfactory method of identifying and testing the workability of concrete.

Brick and Block Pavements.—The use of thinner bricks and blocks has been found to be economical in many cases and its practicability has been indicated by tests. More information on the effect of climatic conditions upon various bituminous fillers is needed. There is still a wide divergence of opinion as to the desirable thickness and quality of concrete bases. It would seem that there must be sufficient information available upon which to base theory and practice in this regard if thorough investigation should be made. This applies also to bases for bituminous pavements.

Development of Equipment

A steady progress in improving and perfecting established lines and types, rather than any striking or new innovations, may be said to characterize the chief developments during 1929 in the field of highway maintenance and construction equipment. This progress has been directed chiefly toward securing greater ease of operation, insuring greater reliability or freedom from breakdowns, and adapting the equipment more definitely to the particular function it is to perform. In many cases these efforts have found expression in the use of automatic or semi-automatic controls, improved power units, better traction, sturdier construction, and more careful attention to the design of details.

The use of automatic or semi-automatic controls which made its appearance on concrete pavers in 1928, has been greatly extended. The question of easy control has also received much attention as applied to such units as power shovels and blade graders. Thus, all along the line engineers seem to be applying the principle that wherever the rate of production is dependent on the rapid and regular performance of consecutive repetitive cycles, the human element should perform the function, not of a power unit, but of a directing agency.

Reliability has always been an important question in highway equipment, but during the past year it seems to have received even more attention than usual. This is probably due to the fuller realization that such equipment rarely operates as independent units, but as a part of a co-ordinated assembly in which the failure of any unit to function absolutely stops production. Higher grade materials and greater attention to the design of details apparently have been resorted to much oftener in securing added strength and ruggedness than the addition of weight or increasing the size of members. In this field there is a rather decided tendency to replace riveted connections with welded joints. This practice of using welded rather than riveted connections has been extended in at least a few cases to include the use of portable welding outfits for many routine field repairs on heavy earth-moving equipment. No doubt a considerable extension of this feature can be looked for in the near future.

The past year (1929) has witnessed a rather distinct increase in the number of the larger types of heavy earth-moving equipment offered by the manufacturers. To some extent this is no doubt due to the fact that the ever-increasing amount of heavy earthwork involved in efforts to provide for present and prospective traffic requirements augmented by that involved in the Mississippi flood prevention program, has created a field sufficient for the profitable use of such heavy equipment.

Of interest in the highway field is especially the appearance of large power shovels and large earth-hauling units, chiefly of the crawler type. An increase is also noted in the use of the Diesel type of power units, while to the gas-air type of power shovel has been added the gas-electric type. Elevating graders have rather widely adopted the use of the power take-off from the tractor drawing the grader, while at least one grader has appeared which is provided with an independent power unit for driving the belt. Large specialized super-scrapers, graders, or grader wagons have also appeared in increased number. Where conditions are suitable their use seems to have been justified.

In the concrete field progress is noted chiefly in a more general use of automatic or semi-automatic operating controls on the pavers and greater refinements in water measurements. Weighing is becoming the usual method of batching, while methods for handling bulk cement have been improved. Efforts to improve surface smoothness have resulted in bringing out heavier or more unyielding forms, one of which is in the form of an auxiliary rail. In batch hauling the solid-tired truck has almost ceased to be a factor, its place being taken by the pneumatic dual tire for all except the smaller sizes.

While one-batch trucks are still used on a great many jobs the movement seems to be toward two-batch trucks equipped with dual pneumatic rear tires. This does not mean that the use of large three and four-batch trucks has been discontinued. Where distance, road, and sub-grade conditions are advantageous, they give excellent service.

The development of central mixing plants, or central batching plants with agitator or mixer trucks, has been especially striking. This movement is still too new to form any worth-while evaluation as to the effect its future development will have on concrete road and street-paving work. While in certain places it is already a strong contestant in the field of concrete street work, further progress is apparently closely connected with the development of a truck body or container which will permit quick unloading and easy cleaning and, at the same time, will prevent segregation during transit. With the very dry mixes now usually recommended for paving the segregation problem should not be so serious.

One of the most promising developments during 1929 has been in the field of earth and gravel road maintenance. For many years the drag, planer, or maintainer has been the standard implement in low-type road maintenance; but it was a slow-speed implement limited to about 4 miles per hour for really good work. Many experiments have at last apparently led to a perfected maintainer which can operate successfully at a speed of 12 to 15 miles per hour and will permit the efficient use of a truck or other high-speed power unit as motive power. What effect the general application of this innovation will have on the future development of this type of surfacing can as yet only be guessed.

Few really new developments are noted in snow removal equipment, and progress has been directed chiefly toward improvements of existing general types, such as providing more power or better traction, higher working speeds, greater mobility for the heavier units, easier operation, greater reliability, better lighting for night operation, and greater comfort for the driver. In State road work the chief reliance seems to be on displacement plows usually attached to the trucks or tractors generally used in regular maintenance or construction work. The more specialized heavy units are largely devoted to throwing back the banks left by the lighter displacement plows or in opening heavy drifts. In the units used for heavy drift work, road transportation speed has been recognized as an important factor; for the ease and road speed at which these units can be moved from place to place largely determines the mileage which can be served by each.

The most striking development in State road work, however, is in drift prevention rather than in direct snow removal. Not only has great progress been made in improving both portable and permanent types of snow fences, but much practical experience has been gained as to their proper location and erection. In some favored sections it has already been possible to arrest drift formation so that the speedy displacement plows can be depended on to keep the road fully open, leaving the heavy units free to be devoted to pushing back the banks. In city and suburban snow-removal work the most notable

feature is the large increase in the use of mechanical loaders. This loading equipment has also made possible the use of larger capacity bodies or extension sideboards on the regular hauling trucks.

Much work has also been done during 1929 on various new ideas and innovations, most of which can be said to be in the experimental stage. These range practically over the entire field of highway work from such varied items as rollers for finishing a concrete pavement to a complete plant for producing bituminous surfacing by a continuous mixing process. Some of these seem promising and may, next year, be reported as accomplished developments. The introduction of a new piece of specialized highway equipment, however, is not a simple matter. The new equipment must not only be shown to function properly of itself, but it must prove itself economically efficient and effective in co-ordination with, and as a unit of, an already highly specialized assembly, every part of which must so operate as to form a single producing plant of exceptional efficiency and sturdy reliability.

Airports

The widespread construction of airports is worthy of notice in that it involves much work of interest to the highway engineer. It is admitted that many so-called airports are nothing more than emergency landing places, being plots of land on which nothing has been done except some very elementary work in the way of development. On the other hand, many airports have been developed in a large way, requiring the expenditure of vast sums of money. Of particular interest to highway engineers are the grading and drainage problems involved and the construction of the take-off strips or runways which are a necessary part of any well-designed and well-equipped airport. These runways are built sometimes as wide as 300 ft. and as long as 2 500 ft.

The problem is much the same as building any road surface in that good drainage and smooth contour of surface are desired. On account of the fact that the surface is not subjected to heavy loads, those surfaces adaptable for light traffic may be utilized. Although the same types of surfaces may be used as for highway traffic, the amount of money available and the local materials at hand are the determining factors which govern the type selected. Surface treatments, the mixing in place of materials with asphaltic oils (so-called processing method), bituminous macadam, bituminous concrete, and cement concrete surfaces, are among those which have been used.

STATUS AND PROGRESS IN THE ART OF POWER ENGINEERING

REPORT FOR THE POWER DIVISION

By Geo. A. Orrok,* M. Am. Soc. C. E.

The field of the Power Division is not alone that of the central station, but includes industrial power, transportation power on land and sea, and the power used on the farm and in the household. For the central station rather accurate statistics have been collected by the Government and the technical press. For industrial power, the Census Bureau gives general figures, but for transportation and agriculture, estimates must be of a much more rudimentary sort. Thurston writing in 1899 gave estimates of the amount of power-producing machinery used in the United States as 6 000 000 h.p. in 1870, 9 000 000 h.p. in 1880, and 14 000 000 h.p. in 1890; he prophesied 21 000 000 h.p. in 1900. Rushmore estimated that this value had grown to 130 000 000 h.p. in 1912. Dr. Fred R. Low, in his Presidential Address to the American Society of Mechanical Engineers in 1924, put the then total as 704 266 000 h.p. A careful estimate as of January 1, 1930 (Table 1), shows a total installation of 1 193 000 000 h.p. of power-producing apparatus or, for an estimated population of 119 000 000, about 10 h.p. per capita of population.

TABLE 1.—Power-Producing Apparatus in United States as of January 1, 1930.

		Horse-power.
Central station	Steam	30 000 000
	Water	15 000 000
	Railway	5 000 000
Industrial power	Steam	20 000 000
	Oil	3 000 000
	Gas	3 000 000
Mining		7 000 000
Stationary, not industrial		5 000 000
Steam railway locomotives		135 000 000
Ships		20 000 000
Agricultural and traction		300 000 000
Automotive		650 000 000
Total		1 193 000 000

If 1 h.p. is assumed to equal 6 man power, the power of the United States to work and the capacity to produce and distribute have been increased in the ratio of 1:60 since the introduction of mechanical power.

Kipling has said that "transportation is civilization," so it should not be astonishing to find that at least two-thirds of the total installation furnishes power for transportation in the automotive, locomotive, and shipping fields. In

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the strictly industrial field about 80 000 000 h.p. is in use at an average load factor of about 30%, giving an output of more than 163 000 000 000 kw-hr. when translated into electrical units, an average annual use of about 1 370 kw-hr. per capita. The central station field producing nearly 100 000 000 000 kw-hr. of energy or, roughly, 840 kw-hr. per capita, has been the most important source from which the Power Division has drawn its material.

The wage-earning portion of the population is represented by 46 500 000 persons, which number includes women wage earners in the home, clerks and stenographers both male and female, and transport workers. Workers in industry alone may perhaps be put at 16 000 000 (other classes being deducted), using 80 000 000 h.p., or about 5 h.p. per worker, an average figure which has never before been approached in the history of the Power Age. This figure was 4.3 h.p. per worker in 1925 and 2.1 h.p. per worker in 1899. The value of manufactured products has increased in a slightly larger proportion, while the wages per worker show about the same proportionate increase. It has been noticed that in other countries as well as the United States the general level of wages is in proportion to the use of power per wage earner.

Organized in 1922, the Power Division has held fifteen meetings at which twenty-three papers have been presented and discussed. These papers have covered a wide range of subjects, including steam and water power, details of construction and utilization, new developments and technical details of power generation, distribution, and use. Research problems in all these lines have played their part in the work of the Division.

Progress since the formation of the Division in the generation of thermal power using coal, oil, or gas as fuel has been continuous and most interesting, but has not been marked by the development of the spectacular advances of earlier times, such as the electric light in 1879 or the steam turbine in 1903. It has rather been a continuous expansion of known and tried methods applied to an increasing and almost insatiable demand for more and more power at a less and less cost. Boilers and prime movers have increased in size fivefold, the 18.5% thermal efficiency has been increased to 27.5%; and the regenerative cycle has come into general use along with superheating, re-heating, and pre-heating. Steam pressures have risen from 400 to 1 400 lb. and in the newest industrial plant to 1 600 lb. per sq. in. where the steam engine instead of the steam turbine has been adopted as the prime mover. Steam temperatures which had been stabilized at 750° Fahr. as the maximum allowable temperature are now being considered as possible up to at least 1 000° while the oil industry is using 1 100° in its cracking stills. The materials for handling these pressures and temperatures have been developed and greatly improved. Welding is replacing riveting and forged and drawn sections are being largely used.

Central station design, due to the great increases in the capacity of boilers and prime movers, has been given a new impetus. Prime movers of the turbine type ranging in size from 100 000 to 208 000 kw., require a much different arrangement from that of stock sizes of 20 000 to 35 000 kw. In 1922, a 50 000-kw. turbine might require as many as six boilers for convenient operation, 10 000 kw. per boiler. One of the three new boilers at the East River Station (New York City) of the Edison Company, has delivered more than

1 200 000 lb. of water per hour, and with one boiler in reserve can deliver 240 000 kw., or 120 000 kw. per boiler. The switching arrangements for a station having three or four large units are many times larger and more costly than the switchboard of a small station, and this necessitates a much more liberal design. The regenerative system means much more complicated auxiliaries to both boiler and prime mover. In some designs as many as eight condensers are used on one turbine with as many as five regenerative heaters. Air heaters often exceed in area the remaining portion of the boiler surface. Piping and valve systems have greatly increased in complication, while the feed-pumps, forced and induced-draft fans, and other auxiliaries absorb as much power as an entire central station generated thirty years ago. The costs of central station construction have been well discussed in a Division paper.*

On the combustion side, the stoker has kept pace with boiler and furnace developments. Pulverized fuel, which had just been successfully used in 1920, has enjoyed an equal vogue. Mechanical oil burners are now generally used where cheap oil is available; and combination burners for oil, powdered coal, and natural gas have been successfully applied in many installations. The water-cooled furnace walls for increased capacity and low furnace maintenance were introduced in 1923 and appear now in most new installations.

Diesel engines and solid injection engines are being used in increasing numbers, while as much as 15 000 h.p. in one Diesel unit has been put in service in a central station in Europe. There are many smaller installations of this type in the United States. Gas engines have not been developed as fast, and few new ones are being installed.

Industrial plants in general have followed the central station in design, but with smaller units, having due regard for the uses of process steam. Bleeder and high-pressure turbines exhausting from atmospheric pressure to 200 to 300 lb. are used in a variety of industries and are most efficient and satisfactory. The burning of waste products, such as sawdust, bagasse, and hogged fuels of various types, has been accompanied by good efficiency and reduction in costs. Regenerating devices, even more complex than in the central station, have been used in many industries, notably in the paper and sugar industries.

In the hydraulic field the same tendencies may be observed. Francis-wheels are now built up to 100 000 h.p. in size for moderate heads, while with higher heads they have invaded the field of the impulse turbine. Impulse turbines as large as 56 000 h.p. are in service and heads as high as 5 400 ft. have been utilized.

The development of the high specific speed wheel has been rapid and continuous. Propeller and Kaplan wheels of large size utilize low-head falls which could not have been developed with the earlier types of wheel. As much as 7 000 sec-ft. of water are used in one wheel and heads from 8 to 60 ft. may now be developed with this type.

* "The Rôle of the Civil Engineer in Power Development," by I. W. McConnell, M. Am. Soc. C. E., *Proceedings*, Am. Soc. C. E., January, 1928, Papers and Discussions, p. 155; *Loc. cit.*, March, 1928, Papers and Discussions, p. 925.

The possibilities of economy, consisting of reductions in cost and increases in efficiency, which are inherent in the testing of small-scale models of hydraulic structures and machines, have been increasingly realized, and many notable experiments of this kind have been made. Many American laboratories are now completely equipped to make experiments of this sort.

Recent investigations of temperature stresses in dams have yielded valuable results, and observations now going on will undoubtedly add to the mass of information already available. The use of belt conveyors for placing concrete removes the time-honored inhibition against dry concrete, and gives the designer the opportunity to specify concrete of the proper water-cement ratio, to give the desired strength and durability.

The use of welding, in the fabrication of penstocks, racks, "specials," scroll cases, generator frames, draft-tube liners, etc., is rapidly extending. With means now available for the non-destructive testing of the efficiency of welded seams, better welds should be made and greater confidence developed in this highly useful and economical means of fabrication.

The measurement of water passing through turbines is becoming much more universal since simple, reliable, and relatively inexpensive means for so doing have been recently developed. Continuous records of plant efficiency, as well as of stream flow, are thereby available, where heretofore the best practice has often been a somewhat refined guess.

The forecasting of stream flow has shown promising and important advances recently, and with the awakening of interest among a greater number of competent hydraulicians, as well as meteorologists, it seems likely that the schemes already proposed will be refined, and confidence in them greatly increased in the near future. Success in this field will have a marked effect on the economics of future water-power development and operation.

Rubber sealing strips set into the faces of upper and lower distributor rings, against which the guide vanes close tightly, have been applied for the purpose of reducing leakage through gates when units are shut down. The quick starting of the units, therefore, does not depend on the previous opening of a valve, which might have been closed. Large rubber-lined bearings have also been used with success in place of lignum vitæ and oil-lubricated types.

The use of pumped water, in combination with a storage reservoir, for the operation of a peak-load hydro-electric plant, has been tried out with notable success at the Rocky River, Conn., development, during 1929. While exact authoritative information as to its efficiency is not available, it is reported to have come up to expectations.

The widespread interconnection and exchange of power between utility companies and districts have made the development and installation of efficient frequency-regulating devices essential. Another device is also in use for automatically controlling the distribution of the load between two or more units, so as to obtain the maximum efficiency from the water used by the number of units simultaneously in operation. These devices have operated with marked satisfaction, both independently and in combination with each other. There is as yet a marked difference of opinion between the school of

thought represented by those who advocate frequency control by a single unit or generating station in a large system, and those who advocate distributing the control among a considerable number of stations or units. While both systems have their particular advantages, it seems probable that with the widespread interconnections which are still rapidly growing, multiple control will inevitably become the accepted method.

The incidence of rainfall and its wide variation from the mean have forced most hydro-electric systems to invest in steam auxiliaries which in some cases constitute a large part of the total installation. Studies of the economies of various relative quantities of steam and water generation, interconnections, and base and peak-load supply have developed methods of division of load leading to the most flexible operation of a complicated system at the lowest cost.

Interconnection on a nation-wide basis has been proceeding rapidly and is being used wherever sufficient diversity exists and frequency differences do not obtain. As an experiment the whole eastern half of the United States from Boston, Mass., to Chicago, Ill., and as far south as Pensacola, Fla., has been synchronized and run as one system for half an hour. It does not appear that such long-distance connections are advantageous for actual transmission, but the use of any portion of the interconnected network is possible and many sections are thus being used in actual daily service.

It has been shown that the use of power is increasing and it would appear, in the special fields covered by the interests of the Power Division, that no signs of a falling off in the rate of increase are apparent. The use of power in transportation, in the workshop, on the farm, and in the home, is so tied in with the present material civilization, is so necessary to the well-being of the American people, and plays such an important part in the daily life of every one, that the work of the Power Division will of necessity grow in interest and importance as the years go by.

STATUS AND PROGRESS IN THE ART OF SANITARY ENGINEERING

REPORT FOR THE SANITARY ENGINEERING DIVISION*

The purpose of this report is to mention briefly certain progressive steps in the science of Sanitary Engineering during the past few years as applied to the purification of public water supplies, treatment of sewage, refuse disposal, and air conditioning. It is not intended as a complete chronicle of advancement in these branches, nor as an attempt to review or establish the status of the entire field.

Water Supply

During the past year or so there has been real progress in that part of the field of water supply which includes improvement in the color, odor, and taste of waters, and in devising improvements in the art of water softening.

Color Removal.—Methods for the removal of color have been greatly refined. In past years methods other than storage depended largely on the unmodified treatment of the water with sulfate of alumina, with and without the addition of alkali, and preceded in some cases by treatment with chlorine.

In many cases where the iron content of the coloring matter is high, it has recently been found that super-chlorination followed by de-chlorination will greatly facilitate subsequent coagulation with the usual chemicals. This is because the chlorine oxidizes the organic matter which, with iron, largely constitutes the color in water. Certain kinds of color are difficult to coagulate and precipitate unless oxidized by storage or super-chlorination.

Chlorine in combination with ferrous sulfate, the so-called chlorinated copperas, has been used by Hedgepeth and his associates for de-colorizing the highly colored water at Elizabeth City, N. C. This chemical used as a primary coagulant and followed by treatment with sulfate of alumina and lime effects a marked reduction in cost of chemicals, besides producing a water of superior appearance.

At the Lawrence (Mass.) Experiment Station, Mr. H. W. Clark has shown that filters loaded with ferric hydrate are efficient for removing color. The direct addition of this chemical in practice is almost unknown, although it has been used experimentally by several investigators—most recently by Mr. Edward S. Hopkins with the turbid and colored Baltimore, Md., water. It will be recognized that ferric hydrate is the coagulating chemical formed when ferrous sulfate and lime are added to a water containing oxygen; it has been used for some time at St. Louis, Mo., New Orleans, La., Cincinnati, Ohio, and other places.

Increased economy in color removal has been effected by controlling the hydrogen-ion concentration of the treated water and by improved mixing and stirring devices. Through the use of the hydraulic jump, the Venturi throat,

* Report prepared for the Executive Committee of the Sanitary Engineering Division by the following Committee: C. A. Emerson, Jr., *Chairman*, H. B. Cleveland, H. F. Ferguson, J. C. Pritchard, and Robert Spurr Weston.

and impellers of pumps, chemicals are rapidly dispersed in water, and the slow velocities, so essential to the formation of well-dehydrated flocs in clear and colored waters, are procured by the use of mechanical stirrers and other basin arrangements. These modifications enable approach to the ideal decrease in velocity, roughly parabolic, between chemical application and filtration.

Filter Operation.—Progress has been made in methods for maintaining filters free from mud-balls in cases where high velocity washing at customary rates does not suffice. The use of air during washing has been of some benefit. Good results are obtained by washing the surface layers of the sand with water applied through a grid of pipes pierced with holes, and placed near the elevation of the surface of the sand when at rest.

Since 1928, a Committee of this Division has been considering filtering material for sewage and water treatment works, and experiments in small glass filter tubes have been conducted at various plants under the direction of James W. Armstrong, M. Am. Soc. C. E., of Baltimore, Md., to determine the optimum size of sand grains and the best depth and grading of sand beds to meet the requirements of waters of different types. No definite findings have resulted as yet from these experiments, but progress was noted in a paper recently presented by Paul Hansen, M. Am. Soc. C. E., at the Convention of the Southwest Water Works Association.

Recently, Messrs. Hulbert and Hering, of Detroit, Mich., in a paper presented before the Central Water Works Association, entitled "Studies on the Washing of Rapid Filters", demonstrated that clean sand is essential to uniform and normal filter operation, and that sand may be maintained in a clean condition by washing at a rate to produce a 50% or 60% expansion of the sand bed. Because the viscosity of water varies with the temperature, higher rates of wash-water application are required for higher temperatures. For example, it was found at Detroit that a wash-water velocity of 30 in. per min. was required to produce a 60% expansion of a given sand at a temperature of 32° Fahr.; a velocity of 45 in. per min. was required to produce the same result at a temperature of 70° Fahr.

Messrs. Hulbert and Hering have shown that these high rates require little more, if any more, wash water in the aggregate; but before they can be applied, the sand must be cleaned. They use a caustic soda solution, together with washing of the sand by a ½-in. nozzle jet.

At Cleveland, Ohio, throughout 1929 the rate of sand expansion during filter washing was maintained at approximately 50%, and Mr. W. C. Lawrence reported a reduction of about 11% in wash-water requirements as compared with the previous year when filters were washed by a uniform rate of application of wash water. Due to this change in method, about 36 000 000 gal. of costly wash water were saved, and filter runs were materially increased without deterioration of the filter effluent. Maintenance of a constant rate of sand expansion during filter washing has likewise proved advantageous at the new St. Louis plant.

Odor and Taste.—Phenolic and chloro-phenolic odors, due to wastes from by-product coke ovens, from gas-works, and from some wood distillation proc-

esses, have been extremely troublesome, especially in the Middle West, and new methods have been devised for their removal. Super-chlorination followed by de-chlorination is efficient in some cases, notably at Toronto, Ont., Canada, but in others it has been found of little value.

Progress has also been made by recovering the objectionable by-products at the coking plant before the wastes are discharged. The evaporation of these wastes by using them to quench the glowing coke from the ovens, which method was unsatisfactory to the manufacturer, is being supplanted by phenol recovery processes based on absorption of the phenolic bodies in scrubbers using light oil, benzene, or caustic soda. The patented Koppers process, efficient in several cases, which uses caustic soda as an absorbent, and which is said to recover from 95 to 98% of the phenols, has recently been installed at Hamilton, Ohio, at a plant which has a daily coking capacity of 1 200 tons.

Baylis, at Chicago, Ill., and investigators abroad, have shown experimentally the efficiency and economy of activated carbon for removing odor due to excessive chlorine or to chloro-phenols. By its use, waters may be over-treated with chlorine, and unpleasant tastes removed with little trouble, at an estimated cost, at Chicago, of $1.50 per 1 000 000 gal. The largest installation of activated carbon filters is the recent one at Barmen-Elberfeld, Germany.

River waters highly polluted by sewage and certain trade wastes sometimes have unpleasant odors and tastes even after treatment with chlorine and coagulating chemicals followed by filtration. These are due to by-products of decomposition. Intensive chemical treatment does not remove them, but treatment with activated carbon is effective and satisfactory.

Pre-ammoniation as a preventative of chloro-tastes as suggested by Sir Alexander Houston, of London, McAmis, of Greenville, Tenn., and others, has been successfully used by Mr. C. H. Spaulding, at Springfield, Ill., in treatment of Sangamon River water which has a high *B. coli* index. Treatment with ammonia prior to chlorination increased the efficiency of the latter process and prevented occurrence of tastes due to chlorine and chlorine compounds. The process is especially efficient when the water has a normal or low pH-value. The process has also been investigated extensively at Cleveland, Ohio.

Among the large plants which have gone into service recently is the plant at Providence, R. I., where both influent and effluent are aerated, and where the mixing and coagulation processes have followed the results of recent research; also, two plants for handling hard and turbid waters at Kansas City and St. Louis, Mo.

At the two Western plants large quantities of silt have to be handled, and mechanical apparatus similar to that of sewage treatment practice has been installed for the continuous removal of the results of both plain subsidence and coagulation. The preliminary tanks, or clarifiers, at Kansas City are circular, whereas those at St. Louis are square. At St. Louis a period of 2½ hours is allowed for removing the silt by plain subsidence, after which chemicals are applied and the treated water is passed through circular mixing tanks. Then follows a 2½-hour period of coagulation in mechanically cleaned

clarifiers, from which the sludge is pumped back into the preliminary subsidence clarifiers. It will be noted that, in these plants, the main improvements are the use of mechanical devices to replace cleaning by hand, and the utilization of the coagulating effect of sludge from the coagulating basin on the silt contained in the raw water.

At St. Louis, it is proposed to over-treat the water with lime and re-carbonate the lime-treated water before filtration, following the practice at plants which are concerned primarily with softening of water, such as Columbus and Newark, Ohio, and South Pittsburgh, Pa.

Water Softening.—This oldest of purification processes has perhaps been changed the most of all during the past three years.

Through the work of Mr. C. P. Hoover and others, the Clark process, now more than eighty years old, has been improved by adding lime in excess, thereby precipitating the magnesium as hydrate and reducing the hardness of the treated water to 25 or 30 parts per million instead of the 60 or 80 parts per million that formerly obtained in municipal practice. The excess lime is removed by subsequent treatment of the causticized water with carbon dioxide gas. Carbon dioxide in concentrated solution is also used to prevent and remove accumulations of carbonates in filters, which were long a troublesome factor in the softening process.

Sodium aluminate is used in some cases in connection with the lime and soda process to provide better coagulation and removal by filtration of the chalky turbidity which results from treatment with lime and soda. Ferrous sulfate also has been used for this same purpose for several years.

Great progress has also been made in the softening of water for stationary and locomotive boilers. Here heat treatment is extensively used to complete the softening reaction, and the chemical treatment has been carefully studied and greatly improved, especially that of waters for modern high-pressure boilers.

The physical and mechanical improvements in the coagulation process which have been used so beneficially for color removal, have been found really essential in the softening process. Here, because of the great bulk of precipitate to be handled, mechanically stirred, and cleaned, re-action tanks and settling basins are rapidly coming into favor. The use of mechanical devices favors the pumping back of sludge to promote precipitation in the basins by increasing the mass of precipitate, an advantage long known to chemists, but not readily taken in practice until the introduction of these mechanical devices.

While the lime-soda process is the one most commonly used, the zeolite process, either alone or as a supplement to lime treatment, is coming into favor for municipal use. The choice between zeolite and soda treatment is determined largely by the relative costs of soda for softening and of salt for regenerating the zeolite. Zeolite without the help of lime treatment is not in favor for extremely hard waters, on account both of the high concentration of the sodium salts which would replace the equivalent calcium and magnesium salts, and of the cost of salt for regeneration.

The first large zeolite plant, that of the Ohio Valley Water Company, has been followed by one at Sewickley, Pa., in which zeolite made from glauconite (green sand) takes the place of the sand in the usual mechanical filter plant. The former of these plants has been in successful operation for more than two years; the latter is newer, but good reports are given of it. In 1928, the Village of South Orange, N. J., installed a zeolite filter, using an artificial zeolite (Doucil). This plant has been in successful operation for about a year. Artificial zeolites have the advantage of greater softening power, but cost more per pound. This additional cost, however, is often outweighed by the higher efficiency and, consequently, the smaller size and cost of the softening apparatus. Most zeolite processes are controlled by patents.

The battle against water-borne typhoid fever has been nearly won, and there are but few supplies in American cities which are unsafe from a sanitary standpoint. Many of the safe supplies, however, are disagreeable and, as standards rise, more and more attention is being given to obtaining waters which are soft and of good appearance. It is in this field that the greatest progress in the art of water purification is being made, and it is in this direction that the older processes are being improved and that more knowledge is resulting in better practices.

Steps for the development of additional sources of water supply adequate for contemplated future needs of great metropolitan areas have recently caused two noteworthy actions at law in the Eastern States to determine rights to the waters of interstate streams.

The States of New Jersey and Pennsylvania have petitioned the United States Supreme Court to prevent the City of New York from carrying out plans for the diversion of a part of the waters of the Upper Delaware River as an additional source of municipal water supply. This suit was instituted after failure of the Legislatures of Pennsylvania and New Jersey to ratify Tri-State Compacts which had twice been proposed between these two States and the State of New York.

The other action refers to the Connecticut River and was instituted in the United States Supreme Court by the State of Connecticut against the Boston Metropolitan District Water Supply Commission to enjoin diversion of the waters of the Swift and Ware Rivers which are tributaries of the Connecticut, through the Chicopee River.

Sewage Treatment

While present-day methods of sewage treatment differ greatly from those of thirty years ago, progress has been gradual and, during the past few years, has consisted of modification and improvement of existing, rather than development of new, processes.

There is increasing official realization of the value of co-operative action by adjoining municipalities forming a natural drainage district for the solution of sewerage and sewage treatment problems, and of the importance of uniform and concerted action on the part of neighboring States, comprising the water-sheds of great rivers, for control of the general stream-pollution problem. This is evidenced by legislation in various States during the past

few years and the subsequent formation of several district or county sewerage commissions, as well as by the agreements entered into by the health officials of the States bordering upon the Delaware and Ohio Rivers and upon the Great Lakes.

There has been an increase in volume of research work and a growing tendency to place sewage treatment works under the supervision of technically trained operators provided with suitably equipped laboratories. Although the number of sewage treatment works is increasing annually, disposal by dilution continues as the prevailing method for the majority of American cities.

While protection of the public health is the major incentive for sewage treatment, there is a growing sentiment for maintenance of streams and other bodies of water in a sufficiently clean condition for recreational purposes, propagation of fish life, and parkway or residential development of the shores. The demand is not only that waters shall be inoffensive to smell, but that they shall be reasonably free from the discoloration and oily sleek of industrial wastes.

The efforts of designers and research workers are still directed toward more intensive methods of treatment, increased protection against offensive odors, and reduction of operating costs. The adoption of recently developed pumps for unscreened sewage, and semi-automatic power equipment to replace hand labor, or manually controlled equipment for various operations at treatment works, is quite common and should tend to an increase in general plant efficiency by the maintenance of more uniform conditions.

Preliminary Treatment.—In a majority of recent designs, particular attention has been given to preparation of the sewage prior to its entry into the sedimentation tanks, by removal of grit and floating solids which are not readily susceptible to digestion, or unusually productive of offensive odors during digestion. Skimming arrangements are often provided for the removal of grease, which has been increasingly bothersome during recent years. At Akron, Ohio, preliminary treatment is provided in short-period detritus tanks equipped with grease skimmers and power-driven sludge scrapers. Fresh sludge is withdrawn to a volume of about 20% of the sewage flow and, after passing through mechanically cleaned grit chambers and fine slotted screens, is returned to the inlet channel of the main sedimentation tanks. Another method is illustrated at Middletown, N. Y., where the entire sewage flow is passed through an automatically cleaned grit sedimentation and washing chamber followed by a mechanically cleaned bar screen having ½-in. clear openings. The skimming of grease is postponed until the sewage reaches the main sedimentation tanks.

Sedimentation Tanks.—Imhoff tanks are still in favor in locations where the necessarily deep excavations are not too expensive. Collection and burning of the gases of digestion for assistance in odor control is practiced to some degree in several places. The plant at New Castle, Pa., is designed for the collection of all the gas and has functioned with reasonable success. During 1929 daily gas production has been estimated at an average of approxi-

mately 0.4 cu. ft. per capita, and during the winter months it is used to heat the plant buildings.

Several installations of single-story plain sedimentation tanks with automatic power-driven sludge scrapers and removers of various designs have been placed in service and are operating successfully. A desirable feature of these installations is the prompt withdrawal of material settled from the sewage, which is advantageous both from the standpoint of digestion of the solids and avoidance of occasional deterioration of the effluent due to gas-lifted masses. The theoretical sedimentation capacity in these installations ranges from about 30 min. to 2 hours, depending largely on whether the units are preparatory to activated sludge treatment or for the removal of practically all readily settleable solids.

Sludge Digestion.—Fresh sludge is being treated successfully in separate sludge digestion tanks. That the period required for digestion of sludge may be materially shortened by the provision of fixed or floating covers for digestion tanks and that the gases thus collected may be used to heat water circulated in coils in the tanks to maintain temperatures favorable for the continuance of bacterial activity during winter seasons, together with control of the reaction by addition of lime, has been demonstrated at Antigo, Wis., Plainfield, N. J., and elsewhere. It is probable that forthcoming designs will provide for less than the present generally adopted storage allowance of 2 cu. ft. per capita.

Sludge Drying.—Glass superstructures of the greenhouse type for sludge-drying beds have been found to increase the number of applications of wet sludge possible throughout a year. The efficiency of these structures is dependent to a large extent on the proper direction of air currents over the surface of the sludge; and the arrangement of ventilating devices is now receiving the increased attention of designers. Comparative data are lacking as to whether the increased capacity of covered beds will be sufficient to offset higher construction costs.

Direct incineration of fresh sludge from settling tanks; de-watering of sludge from various types of settling tanks by continuously operated vacuum filters similar in principle to those in service at Milwaukee, Wis., Houston, Tex., and other places, for excess activated sludge; digestion of sewage screenings; shortening of the sludge digestion period by the maintenance of relatively high temperatures in digestion tanks; and several other associated problems have been investigated in laboratories and studied experimentally with promising results; as yet, however, they have not been confirmed by the continuous operation of full-sized plant units.

With the exception of the Milwaukee installation for the manufacture of high-grade commercial fertilizer, the disposal of dried sludge is by incineration, burial, use on the land, or similar methods which have been in effect for many years. Sludge disposal still remains a problem.

Chlorination.—Chlorination in combination with tank treatment has recently met with considerable favor either for reduction in bacterial content of the effluent or for prevention and control of odors about the works or in

the body of water receiving the effluent. The action of chlorine in the oxidation of volatile products of sewage decomposition has received much study. Some recent designs have provided for the application of the chlorine at the inlet or at a point part way through the sedimentation tanks, thus avoiding the cost of separate contact chambers at the outlet.

Oxidizing Devices.—Trickling filters and activated sludge treatment are the generally accepted methods for the oxidation of sedimentation tank effluents. The continuing popularity of trickling filters is apparently due to their relatively low maintenance costs and to their record of freedom from serious operating difficulties in continuous service for twenty years or more.

Recent installations of relatively small activated sludge plants are producing satisfactory results, and are receiving increasing attention by designing engineers. For the large installations where high land values and the necessity for freedom from nuisance conditions are matters of major importance, the trend is toward activated sludge treatment. This is indicated by the selection of the process for the recently completed North Side Treatment Works, in Chicago, having a capacity of 175 000 000 gal. daily, and for the Wards Island Plant which will serve parts of the Boroughs of Manhattan and The Bronx in New York City, having a dry-weather flow capacity of 180 000 000 gal. daily. In both instances, automatically cleaned sedimentation tanks were adopted for preliminary treatment. At Chicago, the excess sludge will be pumped about 17 miles to the West Side Sewage Treatment Works for digestion in Imhoff tanks; at New York it will be transported to sea after the removal of excess liquid by decantation.

Mechanical aerators for the agitation of the sewage are receiving increased consideration in smaller activated sludge plants, but in larger installations a preference for blowers and porous bottom plates continues.

Refuse Disposal

At present, the preference in the choice of the method of final disposal of municipal refuse is in favor of incineration. This is viewed as sanitary, as most economical, where long hauls are required to proper sites for reduction plants, and as offering a method for combined disposal of garbage and rubbish in one operation.

During the past few years some advance has been made in the consideration of refuse collection and disposal problems on an independent engineering basis, providing for free and open competition under carefully prepared detailed specifications, guaranties, and general plans, particularly as applying to the larger cities.

As concerns installations for the smaller cities, there still is a noticeable absence of adequate engineering service in connection with such important features as plant location and arrangement; economy in regard to provisions for present and future capacity; handling of materials; correlation of collection and transportation problems with plant location and design; and costs of construction and annual operation.

A number of relatively large rubbish incinerators have been installed recently in Philadelphia and in other large cities. Frequently, these installa-

tions include bailing presses, sorting belts, and other equipment to facilitate salvaging of saleable refuse. The wastes as received ordinarily do not contain as high percentages of garbage as those in cities where mixed collection systems are maintained. However, the design of firing and combustion chambers is generally such that, where necessary, an increased percentage of organic matter can be burned without nuisance.

As a culmination of long-standing complaints by New Jersey municipalities against the dumping at sea of garbage and refuse from New York City, the State of New Jersey received permission during 1929 from the United States Supreme Court to sue the State of New York for water pollution and shore littering. Hearings in the case before a special master have been started.

Recent Installations.—Some recent installations have included specially designed ash-handling equipment; provision for the ventilation of ash tunnels and stoking floors; facilities for the ready cleansing of working spaces, storage bins, and equipment; and similar betterments which tend to improve labor and general plant conditions.

A few large refuse incinerators were completed or under construction during the year, including three plants in Brooklyn, N. Y., each with a capacity of 500 tons per 24 hours; one at Montreal, Que., Canada, 300 tons; at Atlantic City, N. J., 240 tons; at Yonkers, N. Y., 200 tons; at Asbury Park, N. J., 180 tons; and one at Racine, Wis., 120 tons. A small 50-ton plant was constructed at the transfer yards of the Pennsylvania Railroad in Pittsburgh, to dispose of waste vegetables and fruit. In addition, there have been more than thirty smaller municipal installations, with rated capacities, ranging from 25 to 100 tons.

Four new refuse incinerators are proposed or under construction in the Boroughs of Manhattan and The Bronx, New York City. It is believed that the recent establishment by charter amendment of a Sanitation Commission to have charge of sewage treatment, refuse disposal, and street cleaning throughout the city, will speed the program for incinerator construction.

At San Francisco, Calif., a proposal to construct a new refuse incinerator was approved in the November, 1929, election, but the record of indecision in refuse disposal matters evidenced in that city in the past has again been emphasized by the defeat of two opposing supplementary propositions, one for public and the other for private ownership and operation of the incinerator.

Air Conditioning

In recent years added impetus has been given to the technical study of air conditioning through the efforts of several scientific organizations.

The study of ventilation may be said to date from the work of Lavoisier during the last quarter of the Eighteenth Century on the chemical nature of air. In 1862-63 von Pettenkofer published the results of studies of the composition of air and a discussion of the effects of carbon dioxide, of the decrease of oxygen, and of alterations of temperature and humidity on the well-being of persons.

It was not until 1902 that specific laws were enacted in Massachusetts to govern ventilation in school houses and public buildings. Similar legislation was adopted in New Jersey in 1903, and in New York in 1904. By 1925 laws or regulations covering ventilation in schools were in force in thirty-one States.

Important contributions to knowledge in this particular science have been made by the Chicago Commission on Ventilation which reported in 1914, and by the New York State Commission on Ventilation which was appointed in 1913 and reported in 1923.

For crowded places, such as large theatres and convention halls, it is generally recognized as necessary that there be a carefully planned mechanical distribution of fresh air of adequate volume, without the production of undesirable chilling drafts or the accumulation of overheated air in secluded spots. It is also recognized that in residences, or less crowded places, adequate ventilation can be secured through open windows. There is, however, a decided difference of opinion as to the relative value of open window or gravity ventilation and of forced or mechanical ventilation as applied to school-rooms, offices, and other places of moderate occupancy.

In general, public health officials through the medium of the American Public Health Association have advocated the open-window gravity system, whereas the proponents of mechanical ventilation have been represented by the American Society of Heating and Ventilating Engineers.

The toxic properties of industrial gases are receiving the attention of investigators. Especially noteworthy is the interest manifested by the U. S. Bureau of Mines in the problem of mine ventilation, which was responsible for the construction of a research laboratory near Pittsburgh, now being operated jointly by this Bureau and the American Society of Heating and Ventilating Engineers.

Respecting progress during 1929, the outstanding event was the design and installation of an elaborate and efficient ventilating system for the Houses of Congress, under the advice and approval of a special committee appointed by the U. S. Public Health Service.

Miscellaneous

Space does not permit comment on advanced methods for the protection of the milk supply, smoke abatement, shellfish protection, mosquito eradication, rat-proofing, and the like, except to record a growing realization on the part of municipal, State, and Government officials that certain phases of these problems properly come within the province of the Sanitary Engineer.

STATUS AND PROGRESS IN THE ART OF SURVEYING AND MAPPING.

REPORT FOR THE SURVEYING AND MAPPING DIVISION

By William Bowie,* M. Am. Soc. C. E.

It would require volumes to set forth in detail the history of the development of the instruments and methods used in surveying and mapping since human beings first tried to determine accurately the location of one point with respect to another and to measure distances and directions on the earth's surface. In the space here available only a bare historic outline can be given.

Surveying and mapping have made tremendous progress within the last two hundred years. Prior to the invention of the direction theodolite by Ramsden about 1787, surveying methods were crude. In fact, one hundred years before Ramsden perfected his theodolite, John Love in his book entitled "Geodeasia: Or the Art of Surveying and Measuring of Land Made Easie," which was printed in London in 1688, made the following statement:

"I have taken an example from Mr. Holwell to make the table of sines and tangents, but to every fifth minute, that being nigh enough in all sense and reason for the surveyor's use; for there is no man with the best instrument that was ever yet made, can take an angle in the field nigher, if so nigh, as to five minutes."

It is evident that at the time Love made this statement the telescope with spider wires or ruled diaphragm had not come into use in surveying, although the telescope had for some decades previously been used in astronomical observations. Even the use of a telescope with cross-wires could not be very effective without an accurately graduated circle. Just what was the status of circle graduations in the time of Love is a question, but this is known, that the graduations on theodolites used in first-order triangulation one hundred years ago were not nearly as perfect as those on the present-day theodolite.

Surveying and mapping have been carried on more or less continuously since the dawn of written history, but the work that was done along these lines prior to about one hundred and fifty years ago would scarcely be considered of sufficient accuracy to meet present engineering needs. Taking land surveying alone, one must realize that in the United States the increased accuracy with which political and private boundary lines have been established and re-run has been due entirely to the increased value of the land. In the early days, when one purchased a piece of property as so many acres more or less, he did not care whether there was much difference in the actual area over what he was supposed to buy or sell. The land was worth so little per acre that he did not feel justified in incurring the additional expense of a high-grade survey. Even the property lines in cities were crudely laid

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down; but now the land in a metropolitan area is so valuable that one must work to the fraction of an inch in establishing its boundaries.

Then, again, there is the surveying and mapping done for the location of highways, railroads, and tunnels. It is only recently that great precision has been used in this work because of the greater sums of money which are devoted to the carrying out of individual projects. At the beginning of the development of the American railroad system, rolling stock was light and time was not a very important factor. The result was that the railroads were laid down in a hit-or-miss fashion with numerous curves and heavy grades. These curves were generally used to avoid heavy cuts or fills, or tunneling. Occasionally, a tunnel had to be cut, but it usually involved only a short distance, and very crude methods could be used in starting and guiding the boring or cutting. Nowadays tunnels extend under rivers, through great mountain ranges, and under cities. The cost of these operations is great, and mistakes in properly laying out the work in alignment and profile will cause serious loss of funds and delays in the completion of the project. High-grade theodolites and base-measuring apparatus are being used for the location of tunnels and bridges, and it seems certain that, in the very near future, the accuracy of the surveying done for the location of highways and railroads will be much more precise than has been the case in the past. There is a gradual but persistent increase in the accuracy of surveying and mapping.

There was a time, a few decades ago, when the subjects of surveying and mapping, which previously had been considered important ones in the curriculum of the civil engineering department of a technical school or university, were given scant consideration by the head of the department, for it was believed that these subjects were not really engineering in character. It was thought that almost any one who had received a high-school education could attend to all the surveying and mapping needed to carry out an engineering project. These subjects were at a low ebb in most institutions of learning for some years. Fortunately for the engineers who are planning big operations and the corporation, individuals, or community furnishing the money to execute them, surveying and mapping have come back in almost full force to the curriculum of the civil engineering department, and even more exacting requirements may be expected of the students in those departments along the surveying and mapping line than have ever occurred in the past. One university, the University of Michigan, has a separate department, under the title, Department of Geodesy and Surveying, with Clarence T. Johnston, M. Am. Soc. C. E., as its head. Professor Johnston, as is well known, has been a member of the Executive Committee of the Division of Surveying and Mapping since its formation several years ago. It is reasonably certain that either the universities and technical schools will have departments dealing exclusively with surveying and mapping, or that these courses will be major subjects in the department of civil engineering.

The great growth of cities, towns, and villages during recent times, the increased use of the automobile, and the desire for rapid transportation, have resulted in studies of the problems involved in bringing many human beings together in a small area. Every settlement of any size to-day has its depart-

ment of city planning. In fact, city planning had hardly become a familiar term before it was replaced, in many instances, by the more comprehensive term, "Regional Planning." People have become tired of letting the community grow up in a haphazard way, and then, later, of having to use vast sums of money collected as taxes to remedy conditions which might have been obviated by a moderate amount of forethought. The city planner is demanding of the engineering department of the community that better maps be furnished him on which to study the many problems that arise, and for which he must work out satisfactory solutions. The topographic map based on high-grade triangulation and leveling enables the city planner and the city engineer to visualize in their true relations the different parts of the area which is a part of, or essential to, the growth of the community.

While much progress has been made in recent years toward improvement in surveying and mapping instruments and methods, there is much yet to be done. Heads of concerns, whether private or governmental, who have for years had their work carried on with the old surveying methods and practice, are not usually inclined to increase the surveying and mapping item of their budgets, even though the increased cost of the adequate surveys and maps might save many times the output in the cost of a project as a whole. Many abandoned highways and railroads, or portions of them which were constructed a long time ago, abandoned factories and power plants, and other structures, all testify to the poor surveying and mapping which preceded their construction. With adequate surveying and mapping data a number of projects would not be carried out, although insufficient mapping data might indicate for them a promise of adequate returns on the investment involved. It may safely be said that good surveys and maps are aids in the elimination of waste in industry.

The Government of the United States early recognized the necessity for making charts of its coasts in the interest of navigation and for the use of its Navy, and maps of the interior of the country for use during military campaigns, and for travel and the transportation of goods. The Coast and Geodetic Survey, a branch of the Federal Government, has been operating along its special lines since 1816, except for a brief period when its work was interrupted. Its first Superintendent, Ferdinand R. Hassler, made a careful study of instruments and methods used by the countries of Europe in charting the coasts. He returned to this country and inaugurated methods which were remarkable in that they have needed only slight changes during the past century. The early triangulation and astronomical work of Hassler are considered to be first-class, even to-day. Other portions of his surveys and charts, except in as far as they have been affected by the work of Nature or man, stand the test of present-day requirements.

The early mapping of the interior on a systematic scale began when the United States Geological Survey was organized in 1878. Previously, expeditions had been sent to the West to map the rivers and mountains and to show where there were passes through the mountains.

The funds made available for the interior surveys did not make it possible to anticipate the needs of engineers and others who require accurate

data in many of their operations. The demands were so great, at times, and the funds so scant, that the Geological Survey was impelled to cover large areas and to publish maps of a reconnaissance character, deeming it better to do this than to survey adequately only small areas and leave the remaining portions unmapped. Fortunately, this condition no longer exists. The appropriation bill of the Interior Department which was recently passed (December 11, 1929) in the House of Representatives carried a substantial increase in the funds allotted for the topographic mapping by the Geological Survey over what had previously been available.

The Budget Report of the President of the United States, made to Congress on December 4, 1929, carried an item of $314 124 for the geodetic work of the Coast and Geodetic Survey. This is an increase of about $225 000 over the amount that is to be used during the fiscal year 1930, which is only $88 600. It will be recalled that at the joint meeting of the Divisions of City Planning and of Surveying and Mapping of the Society, held in January, 1928, a resolution was adopted calling for the completion of the control surveys in a reasonable length of time at a cost not to exceed $5 000 000. These control surveys, as is well known, consist of arcs of first and second-order triangulation and lines of first and second-order leveling. Data furnished by these classes of surveying are absolutely essential to the proper conduct of surveying and mapping and the location of political boundaries of States, counties, and cities, and of private property. Much has been heard of the futility of attempting to make bricks without straw; it would be equally futile to try to make adequate topographic maps and to locate properly boundaries of public and private property without fundamental triangulation and leveling data.

The report of the Director of the U. S. Geological Survey for the fiscal year, 1929, states that about 44% of the area of the United States is topographically mapped. This leaves 56% for which there are no maps that show the configuration of the ground. Of course, there may be maps made by private individuals and corporations for individual engineering projects, but the areas involved are small and the contours are usually based on assumed elevations. Such surveying and mapping is practically valueless in the general surveying and mapping of the country.

With the exception of arcs of third-order triangulation which have been extended by the Coast and Geodetic Survey along the coasts of this country for the purpose of controlling the hydrographic and topographic surveys, this Bureau has executed 20 900 miles of arc of first-order triangulation and 3 700 miles of first-order traverse. This work has been supplemented by 2 000 miles of arcs of first-order triangulation, executed by the United States Lake Survey. The amount of this first-order work is 22 900 miles of arc of triangulation and 3 700 miles of traverse, or a total of 26 600 miles of horizontal control.

The U. S. Coast and Geodetic Survey, the U. S. Geological Survey, the Corps of Engineers of the Army, and several railroad companies have run 55 000 miles of first-order leveling.

It will be seen that a good start has been made toward carrying out the plan of the Coast and Geodetic Survey for the fundamental horizontal and vertical control systems of the country. The plan calls for first and second-order arcs of triangulation and lines of leveling, so spaced that no place will be more than about 25 miles from a triangulation station and a bench-mark. This, of course, means that more than two-thirds of the area of the country will be within 15 miles of fundamental control. Such an amount of work must be considered a Federal project. It is impracticable for the individual States to have geodetic surveying organizations because of the increased cost and also because the triangulation and leveling nets must be single units for the whole country. It is only through a Federal organization that discrepancies in the data along State boundaries may be avoided.

In spite of the great accuracy that is attained in the triangulation and in the leveling, the work is done rapidly and at a comparatively low unit cost. Even the cost of the triangulation now being executed along the Mississippi River, from Cairo, Ill., to New Orleans, La., is low. The cost will not be more than about $100 per mile of progress and the work is being executed at the rate of about 100 miles per month along the axis of the arc. On this arc the costs are increased over ordinary triangulation because of the high trees and the flat country. High Bilby steel towers must be used to raise the instruments above the trees and to overcome the curvature of the earth. The ordinary cost of triangulation where towers of moderate height are used, or in hilly country where only stands are needed for the instruments, is only about $40 per mile along the axis of the arc.

Areas that lie between the arcs of triangulation and lines of levels of the first and second order will be covered by vertical and horizontal control surveys of the third order executed by the topographic engineers of the U. S. Geological Survey, by State engineers making alignment and profile surveys for highways, or by private engineers engaged on other engineering operations than topographic surveying. It is hoped that the first and second-order control surveys will be completed within the next ten or twelve years. The revision of these surveys in the future will cost very little. As a rule, the triangulation stations and frequently the bench-marks, are located in spots which make the monuments rather free from disturbance. Occasionally, the stations and bench-marks should be re-visited and their descriptions brought up to date in order that any one wishing to use them may readily recover and identify them.

The time has come when the value of accurate surveying and mapping should be adequately recognized by the political subdivisions of this country and also by corporations. With the increased size and cost of engineering projects it is wasteful to skimp on the surveying part of the operations. The survey is just as important as the designing of the structure. In the old days when wooden bridges were the rule, it was an easy matter to fit the bridge trusses to the piers. Now with the steel trusses fabricated in the factory and sent to the field ready to be erected, an error of even a few inches in the location of the piers may mean an expensive operation in cutting or splicing the trusses. The use of a high-grade surveying instrument and

a high-grade engineer on the surveying work can obviate any difficulty in making the parts of the bridge fit together.

Another angle from which to view the value of accurate and complete surveys and maps for any given engineering project is that it is only when such data are available that the planning engineer can be sure of securing for his project the one best plan. For most engineering projects many different plans are possible—several of which may be acceptable; a road may go over any one of several routes, a bridge may be located at any one of several different sites, and so with dams, railroads, and other projects; but for each engineering project there is one plan which is better than the others, and one location to fit that plan, and it is to be known only when adequate data make complete comparative studies possible.

There is now a general tendency for engineers to use higher grade instruments than in the past. They are beginning to realize that it is wasteful to purchase a low-grade instrument just because its cost is $100 or so less than one of superior qualities. There are direction theodolites in the U. S. Coast and Geodetic Survey which have been in constant use for thirty or more years. A triangulation party using one of these instruments will cost anywhere from $2 000 to $6 000 per month. How foolish it would be to use any but the best theodolites when the original cost of such an instrument spread over even only ten years is less than 1% of the cost of operating the party.

In leveling operations, the prism level with invar rods, will enable the engineer to secure a very high degree of accuracy in a shorter time than would be possible with the instruments generally used. When the work is done with a high-grade instrument and by a careful and efficient engineer the results are of such reliability that re-running is avoided and no inaccuracies enter into the work sufficient in amount to confuse the engineers engaged on the construction part of the project.

The heliotrope and the lamp are being used more than ever in general survey work where the lines of triangulation are more than a very few miles in length and where a high degree of accuracy is required. It is a simple matter to have a signal lamp, consisting of an automobile headlight with a special filament bulb, which will enable the observer to see over his lines at night when it would be impossible to observe on targets or poles in the daytime. The lamp is especially useful in the triangulation for cities and in connection with bridge and tunnel work.

The use of direction theodolites of a high grade will save much time since a few observations with such instruments will give the required degree of accuracy while many more observations made at greater cost of time and money would be required if ordinary surveying instruments are used. The experience of one observer on the Mississippi River triangulation is an instance of the rapidity with which triangulation can be done. With a 9-in. direction theodolite, read by two micrometer microscopes, he completed the observations over five radiating lines from each of two stations in 1 hour at each station. Thirty-two pointings of the telescope were made over each of the lines, and the two microscopes were read after each one. He thus had 160 pointings on the objects and, since two readings are made with each

micrometer, there were 640 micrometer readings. The observer read one of the microscopes while his assistant read the other. This was exceptionally rapid observing, but at these two stations the seeing conditions were ideal. In general, this amount of observing at a station is done within 2 hours. The average closing error of the triangles on the Mississippi River arc is less than 1″, while the average closing error for the work done during December, 1929, has been about 0.50″. One can readily understand the economy which results from having the highest grade instruments when the greatest part of the cost of the work is involved in the pay-roll.

The Coast and Geodetic Survey has been rather fortunate in general in being able to obtain good theodolites although there have been several instances where the ruling of the Comptroller General has forced its officials to purchase inferior instruments because they were somewhat lower in cost than the high-grade ones. It is hoped that a law may be passed by Congress which will exempt the engineering and surveying bureaus of the Government from the necessity of purchasing surveying instruments from the bidder who submits the lowest bid regardless of the quality of the goods offered. There is such a variety of surveying instruments on the market that one should have a chance to use his judgment and experience in selecting that one which will give the best results; but if the engineer's hands are tied by the laws of Congress and the ruling of the Comptroller, judgment and experience cannot be used. In one decision the Comptroller General ruled that, in the absence of definite and specific information that the goods for which the lowest bid is submitted will not be satisfactory for the purposes for which they are to be used, the lowest bid must be accepted. This means that an instrument must be purchased in order to be tested or that a surveying party must be organized and such an instrument borrowed, used, and tested in order to secure the information required. This, of course, is impracticable and the result is that at times inferior instruments must be purchased. This unsatisfactory condition of affairs should be remedied.

Engineers of States, cities, and corporations are becoming convinced that it is desirable to use, in base and traverse measurements, high-grade steel or invar tapes the lengths of which under certain conditions of temperature and supports are accurately known. The day of the Gunter's chain, pulled along the ground, and with crude marking at its ends, is almost a thing of the past. The field work can be done with the tape at only a small increase in the cost over what it would be with the historical chain.

For many years it was thought that surveying could be done by almost any one, and this idea resulted frequently in the least experienced or the least efficient engineers on the work being put on the surveying and the mapping connected therewith. Many mistakes, some of them costly, resulted from this practice. Too much emphasis was put on the construction end of engineering projects and too little on the surveying. Sad experience has modified the views of those in charge of work of this kind, and now the surveying and mapping are becoming recognized as important parts of the work and are treated accordingly.

There has been in the past a sad lack of co-ordination of effort in making the surveys of this country, both by Governmental agencies and by private corporations and engineers. Much of this loss will be avoided in the future. Ten years ago, President Wilson provided for the better co-ordination of effort by the surveying and mapping agencies of the Government by creating, by Executive Order, the Board of Surveys and Maps on which are representatives of twenty-two agencies of the Government which either are engaged in surveying and mapping or are large users of surveys and maps. The Board has had a useful career and in as far as is permitted by law has prevented duplication and has secured fine co-operation among Government agencies. There is an Advisory Council composed of representatives of engineering societies and other organizations, which co-operates with the Board with the view of disclosing the needs of the public in the surveying and mapping fields.

Members of the Society, recognizing the unsatisfactory condition of surveying and mapping in general throughout the country, created in 1926 the Division of Surveying and Mapping. This Division is making every practical effort to place surveying and mapping on a higher and better basis and to provide, wherever practicable, for co-ordination of effort by the private engineer and corporation. Much more must be accomplished along these lines, and it is hoped and expected that the Division of Surveying and Mapping will have a large part in accomplishing the desired results. There are committees now at work preparing reports and manuals for the guidance of the engineer. The manuscript for a manual on City Surveys has been prepared and is now being put in final form before submitting it to the Society with a recomendation that it be approved and printed.

The alignment and profile surveys of railroads and highways should have been a valuable asset to the country in connection with the topographic surveying and for other purposes. Unfortunately, these surveys were not in general of a very high degree of accuracy and in only a few cases were monuments left to perpetuate the alignment and profiles, and thus make possible the co-ordination of the particular survey with National survey projects. Improvement in this regard is noticeable and surveys of railroads and highways may be expected to be better executed in the future and to be perpetuated by adequate monuments. If this happy result is secured these surveys can be incorporated in the general control surveys of the country.

There has been a tendency on the part of some to consider the topographic mapping as a running expense of the governments of the Nation and of the States. This is wrong. The money spent on them should be considered as a capital investment. The industry and commerce of this country can be carried on at lower costs when the topographic surveying and mapping have been completed. Every community benefits directly or indirectly by the making of a topographic map in any part of the country. A knowledge of the configuration and elevation of the ground and its geographic location may lead to increased agricultural activity, to mining, or other industrial work, and the profits from these industries will lead to increased purchases of manufactured goods or raw materials brought from even remote parts of the country.

While the Board of Surveys and Maps of the Federal Government and the Surveying and Mapping Division of the Society can do much toward improving methods in surveying and mapping, and in co-ordinating the efforts of those engaged in these operations, yet they cannot accomplish all that is desirable. It seems that it would be well if, in each State and in each city, there should be created a commission on surveying and mapping. These commissions should be appointed by the Governors for the States and by the mayors for the cities, and they should serve without compensation. The members of the commissions should be engineers and business men who would be able to advise the officials of the governments in regard to the character of surveys and maps which would best meet the needs of the several political units, and to give advice as to when and where the surveying and mapping should be done. With so many branches of a State or city government, each requesting increased appropriations for its work, the officials responsible for the budget must use more or less arbitrary methods in its preparation. They are inclined to discount the statements made by the heads of departments as being the result of over-enthusiasm or of the desire to increase the importance of their branches. An independent commission actuated only by community interests could give unbiased advice to the budget-making officials with beneficial results to all concerned. Such commissions, appointed for the States and cities, could make contacts with the officials and members of the Board of Surveys and Maps of the Federal Government and of the Surveying and Mapping Division of the Society, with a view to securing adequate and best results.

It would seem probable that in surveying and mapping as carried on by the Federal Government greater advances have been made than in private practice. The Division of Geodesy of the Coast and Geodetic Survey is recognized throughout the world as one of the leading organizations of its kind. Notable improvements have been made in that Division's work in the field and also in the office. The instruments used are of the highest type available and some of them have been designed in the Survey's office, but there is no hesitation in securing instruments that have been designed by other agencies if it is thought they are of a higher type than those designed by the Survey. The design and construction of the Bilby steel tower less than three years ago marked a notable advance in surveying practice, for by its use one is able to extend triangulation over flat wooded country where previously the cost would have been prohibitive.

Great progress in methods of reduction of survey observations has been made in the past thirty years, due in part to the remarkable development of calculating machines. In National surveys this has made possible the economic adjustment of large masses of survey data which, combined with the advance made in practical mathematical methods, has rendered possible and brought into actual being the adjustment of the survey data covering half the country in a single combination of operations. This advance appears also in the simpler forms of plane surveying, where small hand-driven calculating machines may be carried into the most remote fields and used to improve the quality of derived results and the facility with which they are obtained.

The triangulation and leveling of the Coast and Geodetic Survey are probably better monumented than the surveys of any other organization of the country. However, several cities have made accurate geodetic surveys and have monumented their stations in a most substantial manner. One should realize that a control survey made this year may be of value for years to come, and he should go to the trouble and slight expense of putting in station and bench-marks which will remain for many decades unless they are willfully destroyed or worn away by the action of natural agencies.

The U. S. Coast and Geodetic Survey has for years prepared and published manuals on its various classes of surveying. It is only by the use of such manuals that uniformity of projects and high degrees of accuracy can be obtained.

Much progress has been made in the activities of the Coast and Geodetic Survey in its current and tidal surveys of the harbors of the country. The results of such surveys are of great benefit in sewage disposal, and the improvement and navigation of harbors.

In hydrogaphic surveying notable developments have been made in the methods of soundings and of locating ships that are operating out of sight of land. By the sonic sounding method depths of the water can be obtained while the vessel is proceeding at full speed. By the use of bombs, exploded in the water and by the knowledge of the rate of travel of the impulse from the explosion through the water, vessels can be accurately located at distances as great as 100 miles out at sea. Sonic sounding and the method of locating the ships (called radio acoustic ranging) have made it possible to decrease greatly the cost of hydrographic surveying and also to increase the accuracy of the work.

Mention should be made of the use of aerial photography in various classes of surveying and mapping. The airplane method can never entirely supersede ground methods in surveying, but much progress has been made in air work since the World War. There is every reason to believe that still further progress will be made in the future. The airplane at present is used extensively by explorers in obtaining pictures, both vertical and inclined, by which maps of forests, transportation systems, streams, and lakes are secured and also an idea of the general configuration of the country. Such work has been done on an extensive scale in Canada where transportation in many places is difficult, and it has been used in South America and Africa in exploratory mapping.

When overlapping pictures are taken and the necessary devices and instruments used, one is able to make a contoured survey from the aerial pictures. Of course, ground work must be done in such cases to supply the geographic positions and elevations of certain points or objects which will show in the photographs and which are needed in the transfer of topographic features and the drawing of contours from the photographs. Aerial photography is used to a certain extent by the Federal Government as well as in mapping areas for power development, city planning, etc.

There has also been a notable advance made in this country in map expression. Through the co-ordinating efforts of the Board of Surveys and

Maps standardization of map symbols is being attained among the Federal Government organizations. In selecting the proper projection on which to place a map intended for a specific use, there has been marked change since the World War. Where, before the war, the engineer knew and used only such projections as the polyconic and Mercator, he now has knowledge and tables which will enable him to select and use that projection which will best portray those features of his map which he desires to accent. To the engineer the accuracy and facility with which data can be taken from a map are scarcely of less importance than the accuracy with which the map itself can be constructed.

Surveying and mapping have always been the means to an end. They are seldom better or worse than are needed for the projects for which they are made. Increased use of what may be called higher surveying may be expected in the years to come because of the great increase in the value of land and in the amounts of money that are involved in engineering projects. The Engineering Profession will be wise to anticipate in its surveying activities the needs of the construction engineer and owners of property.

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HIGHWAY DIVISION

JANUARY 16, 1930—10:30 A. M. TO 12:30 P. M.

HIGHWAY CONSTRUCTION MANAGEMENT

By T. Warren Allen,* M. Am. Soc. C. E.

"The aim of construction management is to do things properly in the least expensive way." With these words Mr. Allen introduced himself directly into the very heart of his subject and then developed his thesis as applied to the great industry of highway building. Examples of mismanagement or poor management could be given in great numbers, but Mr. Allen contented himself with only a few instances in which co-ordination between the various interdependent parts of road projects had been sadly lacking to the great loss of the public as far as the ultimate cost was concerned.

Designing to Reduce Cost.—According to Mr. Allen,

"The influence of design on construction management and costs is very far-reaching. In the case of a bridge, for example, the design very largely controls the methods which can be employed in both the fabrication and the erection. In the case of the highway itself the design usually includes many items which vary widely, depending on whether the designer gives real thought to his work and is familiar with the construction problems involved or merely follows the lines of least resistance. The average designer in dealing with the item of grading, for instance, is quite careful to balance his cuts and fills but usually fails to give sufficient consideration to the lengths of haul he imposes or to how widely or frequently these lengths may fluctuate. Inattention to these details renders it very difficult if not impossible for the contractor to properly adjust the size of his hauling outfit to fit the work to be done and increases the cost materially."

Taking an actual example of one grading project involving a power shovel, he showed how the average haul on consecutive days over almost two weeks varied from 200 to 1 100 ft. Obviously, the equipment would be in varying demand. Either the shovel would be overloaded and the wagons would be waiting, or all the wagons would be busy while the shovel was waiting. This is on the assumption that a reasonable average amount of equipment was provided to minimize the losses. Even so, however, the average loss amounted to about $50 per day.

Government Studies.—Intensive investigations over several years on the part of the U. S. Bureau of Public Roads covering highway methods and costs have involved detailed stop-watch analyses of various activities on many road projects. By covering the entire country, it has been possible to segregate the results by districts. Also it has been feasible to help individual constructors for their immediate and future guidance.

* With Chf., Div. of Management, U. S. Bureau of Public Roads, Washington, D. C.

Arbitrarily, a period of 15 min. has been adopted as the dividing line between major and minor time losses. Another sub-division is into classes of those which hardly could have been anticipated (Class A), such as interference of the elements, and those which might have been avoided by good management (Class B).

As Mr. Allen explained, the large losses are so apparent that they are studied closely. The minor losses, however, so often neglected, actually consume from 20 to 50% of the total time of the crew on the average project.

Quoting statistics taken from almost a hundred concrete paving jobs, Mr. Allen gave the following:

MAJOR TIME LOSSES.

	Percentage.
Rain	9.5
Wet sub-grade	8.0
Lack of prepared sub-grade	3.0
Lack of materials	3.5
Moving plant set-up	3.5
Inadequate supply and faulty operation of hauling equipment	3.0
Mixer trouble	2.0
Lack of water at mixer	2.0
Loading plant trouble	1.5
Miscellaneous causes	4.0
Total	40.0

Even the remaining 60% is not unalloyed work; about one-quarter of it is lost in:

MINOR TIME LOSSES.

	Percentage.
Supply and operation of hauling equipment	7.3
Lack of, or trouble with, water at mixer	1.9
Lack of materials and supplies in place	0.7
Mixer trouble	1.1
Mixer operator	1.3
Finishing	0.4
Sub-grade delays	1.6
Miscellaneous causes	1.3
Total	15.6

"In other words, the average concrete road-paving contractor is not only out on the road with his crew but about 60% of the available calendar hours, but during this time he is actually operating at only about 74% of the rate which his key equipment is capable of maintaining."

Similarly startling results were obtained from studies of road grading with a power shovel, based on about one hundred jobs. Major delays amounted to about 30% and minor losses to 27 per cent. Detailed subdivision of time losses shows that "the average contractor probably loses more money through shortage of hauling equipment than from any other controllable cause." Considering that many operating costs continue, whatever the output, it is seen that high production efficiency is much more economical than appears on its face.

Frequently the observation is made, continued Mr. Allen,

"That it is no concern of the engineer whether the contractor makes or loses money. With but few exceptions, the cheapest method of construction is by contract, and we must have a prosperous contracting fraternity if we are to have our work well done. Increased efficiency in contract work will ultimately be reflected in lower bid prices. Highway contractors are to-day, probably without realizing it, bidding on a basis of doing work at a little above 50% efficiency. Some of the contractors are doing a profitable business and some are not. The proper procedure for all of them in order that they may do a more profitable business, should be more efficient management rather than increased prices."

Reduction of Losses.—A knowledge of the losses makes it possible by intimate study to eradicate them. For example, the poor location of hauling units for loading by a power shovel may increase the bucket cycle by as much as 5 sec. "In good common excavation, the elimination of this one delay alone may mean an increase of from 20 to 25% in the rate of production".

Studies were made on one Portland cement paving project about 12½ miles long last summer (1929). As a result of the specific changes and improvements introduced, "the efficiency of the job increased from 78.8% for the week ending August 24 to 88.4% for the week ending September 14 and to 98.2% for the week ending October 5."

Equally striking were the results from a concrete paving job in Wisconsin on which studies were made between June and August, 1929. The amount and variation in the delays during this period are shown by the following results of production studies.

Causes of delays.	Time Losses, in Percentage.		
	June.	July.	August.
Mixer operator	2.3	2.8	1.7
Mixer mechanical	1.4	1.2	1.2
Truck operation	4.6	4.0	3.7
Truck supply	13.0	7.6	1.6
Installing joints	0.9	4.0	2.1
Sub-grade	2.1	2.0	1.9
Water supply	2.4	1.4	2.2
Moving plates (track for trucks)	1.0	0.7	0.3
Materials	1.3	0.0	1.3
Miscellaneous	2.3	1.7	2.4
Dry batches	0.0	0.7	1.0
Total	31.3	26.1	19.4

During this time the average production was increased from 1 526 sq. yd. per day in June to 2 025 sq. yd. in August, with a corresponding decrease in cost from $1.44 to $1.26 per sq. yd., or a saving of 12.5 per cent. It will be noted that almost all the economy is accounted for by attention to the one item of "truck supply".

Rules to Increase Efficiency.—The results of all these studies pointed to the definite value of a few simple rules. Stating these in Mr. Allen's own words:

"The rate of production is so dependent on the performance of the key equipment as to demand that it always be maintained in good mechanical condition, and to forbid the employment of anything but a high-grade operator.

"Auxiliary or dependent equipment which is of insufficient capacity or which cannot maintain the rate demanded by the operations of the key equipment should not be tolerated. This applies also to the operators of such equipment.

"The use of equipment or methods of operation which cannot readily be adapted to operating efficiently in connection with the assembly or outfit as a whole or to sustaining economically the production rate of the key equipment should be avoided.

"But an assembly of men and equipment, no matter how fine, is practically worthless as a producing unit until supplied with a directing head, as on the managerial ability which it exercises depends, not only the rate of production obtainable from any construction outfit, but, also, the unit cost at which such production is secured. Real managerial ability to run the job as a whole is essential to high rates of production, low unit costs, and best possible profits. But if we are to reap the full advantages which management offers in translating our designs and plans into realities, we must also develop a spirit of mutually helpful co-operation and understanding between those who manage and those who plan and supervise. The relation of costs and quality are so inter-woven that the ideal adjustment can never be attained except through mutual co-operation and assistance."

CONSTRUCTION MANAGEMENT

By Richard Hopkins,* Esq.

Successful Bidding.—Efficient management of construction work, according to Mr. Hopkins, consists first of all in obtaining the contract. In fact,

"Intelligent bidding is the first requisite of good management. Anything which is well bought is half way along the road to being well sold. A lemon on the day of the letting scarcely ever becomes a ripe plum when the final ledger accounts of the job are closed."

If a contractor obtains 20% or more of the work on which he bids, that is conclusive evidence *per se* that he is not a good bidder. In fact, less than 10% of success is a far better criterion. This means that he should not wait until he is through with one piece of work before trying to find another; otherwise,

"The result is likely to be bad from three angles: The new work may not be the right kind of a job; it may not be obtained in time; and the price may be much too low."

Computations for the field cost based on the contractor's own record are adjusted for an estimated over-head expense. These are relatively simple matters. Then comes the question of contingencies, which may involve soil conditions, weather prospects, co-operation with other contractors, and the time effect of bridge or other construction. Finally,

"The amount added for profit will depend on whether the bidder is hungry or whether he is filled up. It will depend on whether or not the job is in a market that has more than its share of labor troubles. It may vary through a wide range, depending on whether it is largely a labor job or largely a material job, and on the definiteness or indefiniteness of the engineering inspection that can be expected."

* Pres., Richard Hopkins Constr. Co., Albany, N. Y.

Planning the Work.—The first and most important operation for the success of the work is the choice of the superintendent who,

"Should be a real leader, a friendly czar, a man who knows all the letters of the construction alphabet, and, above all, a man who knows how to plan and how to get performance and who knows how to devetail the different operations into a completed whole."

The foremen should be similarly carefully selected. Not only should there be a foreman for each particular operation, but his responsibility for the task should be a definite one.

As regards accounting, Mr. Hopkins advocated a combination of engineering and accounting work under the control of a trained engineer. Only the engineer can combine the qualities necessary to handle items of extra work, special measurements, and necessary departures from plans and specifications.

Equipment.—One of the items of growing importance is that of purchase and care of equipment. Twenty years ago, perhaps 85% of the cost of a grading job was wages; to-day, most of the operations, major and minor included, are done by machinery. Hence, in Mr. Hopkins's opinion,

"Next to the superintendent the master mechanic is the most important man on the job * * * When the purchase of any piece of equipment is contemplated, his opinion should be asked on three questions:

1.—Is the machine staunchly built?
2.—Is it well designed?
3.—Is a large repair bill or a small repair bill bought with the machine?"

Extending down through the organization a similar capacity and competency should apply to all the subordinate positions in the mechanical field. To draw an analogy from common experience,

"Physicians and hospitals exercise a big part in our every-day life to keep us in good health. The construction physician is the master mechanic, and when he and his internes, the machine operators, all know their jobs, the piece of construction under their hands is in good financial health."

Sometimes, contractors make a fetish of maintaining a schedule. Superhuman efforts are made to equal or exceed some imaginary standard. Others rely more on an orderly progress with a moderate schedule. This may not involve record days of work, but it may yield good weeks', and wonderful months', progress. After all, the final cost is the best criterion.

Drawing an analogy from the old axiom that no well-conceived military operation can be a success without good infantry, Mr. Hopkins concluded,

"No construction operation can hope to be successful without good laborers. Good labor is satisfied labor. The turn-over is small. Their length of service is measured in years, not in days or weeks. Their camps are clean, their food is good, they know that the superintendent is a fine boss and always treats them square. They boast a little about how much better they are than the outfit on the other side of the ridge. Underlying it all is the firm conviction that they know their job and that the boss knows his."

GENERAL DISCUSSION

In appreciation of the papers delivered, C. D. Curtiss, M. Am. Soc. C. E., Secretary of the Highway Division, expressed the hope that wider publicity

could be given to the principles and methods described. This view was seconded by A. P. Greensfelder, M. Am. Soc. C. E., speaking for the Construction Division. Both groups, he felt, could profit by study of these matters. There are great possibilities of improvement; incidental to better management, Mr. Greensfelder recorded the views of contractors who "believe, as an economic matter, that there will be more construction when construction is more economically performed."

He pledged the co-operation of the Construction Division in any further publicity or discussion for these valuable papers.

EQUITABLE DISTRIBUTION OF LICENSE FEES AND GASOLINE TAXES

Digest of Previous Papers.—Thanks to A. N. Johnson, M. Am. Soc. C. E., a summary of the previous extensive discussions on this topic at former meetings of the Division had been prepared and was supplied by the Society in printed form. This gave a basis for the morning's discussion. After explaining the plan under which the topic had been covered in the several programs, Dean Johnson's summary went on to review in condensed form the arguments presented at the meetings in Dallas, Tex., Milwaukee, Wis., and Boston, Mass., as reported in considerable detail in previous Society publications.*

GENERAL DISCUSSION

Regretting that the disclosures of the various studies were so much a matter of personal opinions rather than deductions from scientific data, R. W. Crum, M. Am. Soc. C. E., stated that recourse should be had to,

"The old principle of taxation that the public improvement should be assessed against the benefited parties in proportion to their benefits * * *. There are three principal parties who benefit in improved highways: (*a*) The communities benefit, including in that all kinds of communities, from the smallest on up to the National Government; (*b*) the abutting property benefits in greater or less degree; and (*c*) the user of the highway benefits."

The proceeds should then be divided between the three classes of projects affected, namely, the municipal streets, State highways, and country roads.

Experience in St. Louis.—The standpoint of the ordinary citizen who seldom uses the pavement but who has to pay taxes to provide for commercial vehicles was espoused by R. B. Brooks, M. Am. Soc. C. E. In St. Louis, Mo., a 36-ft. roadway was taken as the standard required for residential use, any amount exceeding this width was considered due to other causes (such as commercial and through traffic) and a matter of payment out of bond issues.

The City of St. Louis is in a peculiar situation politically, inasmuch as it is a separate entity and not part of any county. State bond issues in the

* *Proceedings*, Am. Soc. C. E., August, 1929, Papers and Discussions, pp. 1393-1398; October, 1929, pp. 2053-2060; and December, 1929, pp. 2567-2575.

amount of $135 000 000 total have been expended or authorized. To this the City has contributed 20%, or more, without any return. Mr. Brooks cited this as another instance of inequitable distribution. The State has made a partial recognition of urban need by setting aside about $15 000 000 of the recent bond issue to improve the means of access to the main cities. In this way St. Louis will have the advantage of 40-ft. roadways within a radius of 20 miles of the city.

The municipality has passed a local ordinance to bring in a ½-cent gasoline tax for its own use. Admittedly this would not be considered constitutional if taken to the State Supreme Court; hence, no one has ever tested its constitutionality and it has become "really a voluntary contribution by the motor organized industry of St. Louis. That has gone on for a number of years and still continues."

Helping the Small Town.—Emphasizing the importance of the problem under consideration, Hugh Miller, M. Am. Soc. C. E., quoted statistics which tended to show that one-half the total power of the United States was used on highways.

Fundamentally, Professor Miller asserted,

"The problem we have here, whether we recognize it or not, is really Government ownership of the highways * * *. We would vote down Government ownership if it came up in connection with the railroads. Then we have private rolling stock and that makes a different problem from anything we have had to deal with in the past."

Due to the newness of the problem, the solution has thus far evaded the efforts of engineers and officials. The result has worked hardship on the municipalities especially, and many of these smaller cities and towns have been unusually hard hit. He instanced the objection voiced during discussions at previous meetings, emanating from various States. Ordinary observation, Professor Miller asserted, would show conclusively that,

"The small town was discriminated against * * *. The through road is an express highway and it is all the officers can do to slow down traffic to 30 miles per hour to protect school children and old people. In other words, the State takes that one street and makes it a dangerous artery, and instead of its being a benefit to the small town, it is a detriment. The only way to get away from that is to build new streets around in back of the town and let the through traffic have those streets to themselves. That imposes an additional burden on the towns."

Medium-sized cities are little better situated. Professor Miller cited the conditions in Schenectady,—city streets crowded with tourist traffic in summer and with heavy through trucking the year around. In his opinion, "the smaller the town, the more it suffers". By-pass highways should be furnished at State expense. The town would lose little, if any, business and would gain immeasurably in every other respect.

Large Cities Also in Straits.—It might be expected that the City of Detroit, Mich., which receives the greatest financial benefit from the automobile business, would suffer least. Not so, explained A. H. Place, M. Am. Soc. C. E. Speaking from the standpoint of the automobile city, he explained,

"Our problem consists essentially in that of street widening. The city has been able to finance road improvement at the rate of one hundred miles a year during the last eight or ten years, but the congestion has become so great on the streets that are part of the State and National highway systems that under the master plan adopted by the Rapid Transit Commission of the city, the city is up against an impassé now and does not know how to go about the problem of widening the streets."

Special assessments were considered, but apparently they would have created too great a tax burden. As it is, grade separations and street widening already take about $4 000 000 yearly. Of necessity, the remainder of the program has to wait. A recent suggestion has been to divide the highway and gas taxes in three parts, one-third to the State, one-third to the counties, and one-third to the cities, townships, and villages. As Mr. Place conceives it, "the re-division of these funds is so eminently a political proposition that mere engineers are not going to get very far in solving it."

Conditions around Philadelphia, Pa., received a thorough airing at the hands of C. E. Myers, M. Am. Soc. C. E., and H. J. Sherman, M. Am. Soc. C. E. Actually out of $100 000 000 of State bonds, the City of Philadelphia has not received any assistance. Possibly, Mr. Myers contended, the 20% share according to relative population might be too high; on the other hand, the 1% share on the basis of area would be entirely too low.

The small communities have one good argument, according to Mr. Sherman, from the fact that by far the great majority of highway users originate in the city. The State, therefore, might well take over the responsibility for laying out and building these highways through small towns and villages. To Mr. Myers' contention that the city should have a large say in how the money should be spent within its boundaries, Mr. Sherman argued that city control might too easily result in an improper diversion of the funds.

Continued Study Authorized.—The discussion then reverted to the proper way for having the excellent results thus far accomplished in this study continued under the auspices of the Division and to its credit. During the course of the extended comments, it was agreed that the by-passes around towns were essential and should be built at State expense. The final action was to authorize the Executive Committee of the Division to continue the study by special committee in such a manner that specific recommendations could be brought before the Division for action, at the next Annual Meeting.

Viewing the highway business as a whole, F. J. Mulvihill, Assoc. M. Am. Soc. C. E., commented on the tremendous proportions of the problems confronting engineers. With 250 000 miles of highways yet to be provided with high-class surfacing, a potential expenditure of $12 500 000 000 is in prospect. The total revenue from automobile and gasoline taxes he estimated at $700 000 000 yearly. So gigantic is this problem, he urged, that it demands the greatest constructive thought by highway engineers to guard the prosperity and success of the Nation.

POWER DIVISION

JANUARY 16, 1930—10:10 A. M. TO 12:30 P. M.

After calling the meeting to order, Chairman L. J. Bevan introduced H. de B. Parsons, M. Am. Soc. C. E., who had been requested to read an abstract of the paper by A. H. Markwart, M. Am. Soc. C. E. Preprints of this paper had been made available beforehand.

STATE SUPERVISION OF THE DESIGN AND CONSTRUCTION OF DAMS

By A. H. Markwart,* M. Am. Soc. C. E.

Popular Interest in Dams.—Any effort to impose State supervision must have popular support, and the task of arousing public interest will evidently be an important item in any program to secure regulation of the design and construction of dams. The problem was stated by Mr. Markwart as follows:

"The failure of an engineering structure, unless attended by loss of life or property, does not usually attract the attention of the layman. When such a failure results in damage to property only, it is of interest to the owner or owners of the structure and to the party or parties damaged. When, however, the failure involves loss of life as well as damage to property, it becomes a tragedy which is the subject of great concern to the general public."

Touching briefly on the St. Francis Dam disaster, Mr. Markwart said:

"What the failure of the St. Francis and other ill-fated dams teaches, is the necessity of introducing greater conservatism and sounder judgment, particularly the latter, in the design and construction of such structures."

Necessity for Supervision.—In the judgment of the author, avoidable defects in dams can be eliminated almost entirely with effective regulation and control, but,

"In exerting supervision over dams, the State is merely exercising one of its police functions in the interest of the public. State supervision of dams is desirable if properly done, and undesirable if not properly done, since it then gives a false security to those who place their trust in its protection."

Mr. Markwart outlined the distinction between State interference in private affairs and State protection of life, health, and property. Much of the need for various kinds of regulation would disappear if individuals, corporations, and local governments would impose necessary self-discipline to eliminate the risks, but human nature is such that this control from within is not to be expected. On the other hand,

* Vice-Pres., Pacific Gas & Electric Co., San Francisco, Calif.

"The value of State supervision does not consist in requiring of the owner the employment of a consulting engineer, but rather in requiring an independent review of the design, insuring the application of more than one mind to the problem."

Legislation in the United States and in Europe.—The States of Colorado, Idaho, Massachusetts, New Jersey, New York, Pennsylvania, California, and Washington have statutes bearing on this subject. France has regulated the design and construction of gravity dams since 1897, and is now extending its regulation to other types. Great Britain and Italy, in recent years, have adopted regulatory measures, those of Italy being most comprehensive. To quote Mr. Markwart:

"It is of interest that, in nearly every instance, the regulations were prompted by some dam catastrophe which impressed the necessity for such regulations upon the minds of the people."

Characteristics of Supervision.—The best type of legislation, he declared, must be "well considered along sound lines and neither difficult of compliance nor needlessly extravagant in its effect upon costs". Engineers, especially civil engineers, should take a leading part in securing this legislation; according to Mr. Markwart:

"They should study the problem with a view to directing public opinion along lines not subversive of the best public interests. They should discourage anything in legislation which would tend to hamper the fine progress in the development of dam construction which has characterized the art."

In general, he advised against the creation of new governmental agencies to administer the statute itself, recommending instead the maximum use of existing governmental machinery. The statute should be confined to basic principles, he stated, bearing in mind the limited objective of safe-guarding life and property.

Extent of Supervision.—The Supervising Board should not attempt to influence the initial planning of a project, the design, construction, or choice of site, but should limit its scope to an approval of the plans and activities of the petitioner for a construction permit. In the words of Mr. Markwart:

"If State supervision is to be established, it should be inclusive of the entire undertaking. It should involve, in so far as safety alone is concerned, the approval of the location, the design, the construction, and the maintenance of the dam. Such supervision should not involve the independent selection of the location or the design, the superintendency of construction or the direction of maintenance on the part of the State, for the reason that such a procedure would result in a tremendous duplication of effort and expense and an unwarranted interference in the affairs and plans of the owners."

The petitioner, on the other hand, should submit a report pertaining to the geology of the site and the flood run-off conditions of the water-shed. This report should contain plans and specifications of the proposed dam. Finally,

"The State authority, in addition to its responsibilities over new construction, should also have the power to condemn unsafe structures, to order water removed or lowered, or to limit permanently the height to which water may be stored, where existing dams are found to constitute a menace."

Mr. Markwart recommended that there be no exceptions to the class of regulation because of ownership, and that,

"Dams built by individuals, private corporations, quasi-municipalities, counties, and the State itself, should be subject to the same supervision." However, "Dams built by the departments and bureaus of the Federal Government may not be subject to review by State authorities, due to lack of sovereignty." Furthermore, "Some exemption should be made for unimportant structures, the failure of which would not involve loss of life and property."

The personnel of the Supervising Board is an important consideration, he said, and,

"Those in supervisory capacity on behalf of the State Government must obviously be the peers in technical experience and judgment of those engineering, designing, and constructing the dam, in order that the decision of the supervisor may be unquestionably sound".

It was proposed that the burden of costs entailed in establishing this system be divided as nearly as possible between the State and the owners and operators of the dams.

Maintenance of Dams.—Generally, past performances should be conclusive evidence that a dam has been built satisfactorily. However, it may be desirable for the Board to examine the operating history of many existing dams. In many cases, the owners might properly be called upon to show cause why some dams, because of depreciation, etc., should not be replaced.

Appeal Provision.—Recognizing the need of providing means for a petitioner to protest the ruling of an Advisory Board, Mr. Markwart suggested the regular Court appeal. In addition, he recommended that,

"An alternative method of review could well be provided, namely, the right to present the questions at issue to a board of engineers acting as arbitrators, one of such board to be selected by the State Engineer, one by the builders of the dam, and a third to be selected by the first two named. The decision of this board should be final. The expense of the hearing before this board should in every case be divided between the State and the party making the reference, since the State would never make the reference in its own behalf, and the cost of the arbitration would otherwise fall, invariably, upon the private appellant."

All important dams should be inspected, perhaps bi-annually, said Mr. Markwart, because,

"Such an inspection would operate to guard against malicious and insincere complaints respecting existing structures." Furthermore, "State supervision, due to its perpetuity, offers a continuing control over structures of this type, outlasting the lives of the designers and builders."

Building Code for Dams.—Relative to codes to cover the construction of dams, Mr. Markwart stated:

"While it is recognized there are many disadvantages in the codification of anything, and that a code for the building of dams would be more difficult to devise than would be a code for buildings, it is not impossible, should a code be considered otherwise desirable, that a competent group of engineers could fashion a comprehensive and workable one, at least as far as certain important features for the building of dams are concerned".

With this viewpoint as a basis, Mr. Markwart outlined, very briefly, his ideas on the usefulness of such a code. He classified the well-known dams under six headings:

"Earth dam (rolled or hydraulic fill).
Rock-fill (dropped rock or rubble rock).
Rock masonry.
Concrete (gravity, arch, multiple arch, or buttressed slab).
Crib (generally wood and occasionally concrete).
Frame (steel, wood, or concrete)."

Continuing, he declared that,

"It would be possible to prepare a code to cover the building of dams which would describe the conditions under which each of the dam types could be built, from which a builder could select a type, providing the economics in the particular situation did not make the structure entirely unfeasible."

Conclusion.—Deploring the grievous loss of life that has accompanied the failure of dams, such as the St. Francis, Mr. Markwart pointed out that, nevertheless,

"It is not more deplorable than the loss of life which occurs through modern instruments of production and transportation. No one would consider for a moment abolishing automobiles because of the tremendous loss of life which takes place through their existence. Consequently, a disaster like that of the St. Francis Dam must not occasion unnecessary capital investments and of such an order to prohibit the conservation of water for the various uses to which water is put."

He concluded by recommending that the general subject of dams, especially legislation relating to their regulation and control, be made the subject of study by a special committee of the Society. Its object should be,

"To outline a type of uniform legislation which it would be best for the States to enact, since the conditions which it is desirable to control in the various States are not so diverse as to preclude the successful operation of such a uniform act."

DISCUSSION

THE NEED FOR FURTHER STUDY, CO-ORDINATION, AND STANDARDIZATION

By W. P. Creager,* M. Am. Soc. C. E.

"There is no branch of the Engineering Profession in which there is less co-ordination and standardization than among the designers of dams. Moreover, the theory of the design of dams is changing at the present time very rapidly, and new principles are being employed by some engineers and not by others."

According to Mr. Creager, these conditions make necessary a study to determine a uniform basis for controlling the design and construction of dams.

* Vice-Pres., and Chf. Engr., Northern New York Utilities, Inc., and The Power Corporation of New York, Watertown, N. Y.

Commenting on the proposed nature of supervision, Mr. Creager stated,

"It seems very necessary to prohibit the building of dams under the personal direction of only one man. I certainly am in favor of a certain amount of supervision over the design and construction of dams. Only too frequently has incompetence or greed led to disastrous results. In the interest of lives and property and for the reputation of the Engineering Profession, there should be some means by which the design and construction of dams can be held within safe bounds. If, as I firmly believe to be the case, this happens to be the consensus of opinion, our problem will consist in the determination of the most practical kind of regulation."

Apparently, effective regulation is possible only by means of legislation, and many States have such regulation in force. As between supervision by a single employee of a State and a board of consulting engineers appointed by the State, Mr. Creager preferred the latter; but even that might be impracticable under present conditions.

"An alternative would be supervision by an individual with the right of appeal, on the part of the builder, to a consulting board. At the present time there is no right of appeal except by due and slow process of law."

In urging the appointment of a Special Committee of the Society to investigate the design and construction of dams, he declared that,

"The appointment and subsequent report of such a committee or of a joint committee of the major Engineering Societies or by the Federal Government to standardize the design and construction of dams would go far to assist in effective, consistent regulation."

SUPERVISION OF DAMS IN CONNECTICUT

By Charles Rufus Harte,* M. Am. Soc. C. E.

In addition to the eight States listed by Mr. Markwart as having State regulation of dams, Mr. Harte called attention to the Connecticut law on this subject. He also outlined some of the general advantages of a central organization to supervise the design and construction of dams. With such an organization, he said,

"There tends to be accumulated very valuable data where it is, or should be, readily accessible, and which should be of much help to all concerned with dams and reservoirs."

Furthermore,

"The criticism of regulatory supervision has been that it may add to the cost. But that perhaps is not entirely without certain advantages. If there could be brought to the minds of the public, certain parts of the public, a real appreciation of the real costs of water power, I think we should have less of the unwise agitation for States to take over that which they think is an enormously profitable proposition."

Mr. Harte recommended that the law should apply to all dams, regardless of size, at which any hazard exists. In November, 1927, it was the failure of small dams in Northern New England that caused most of the damage during that flood. In his own words,

* Constr. Engr., The Connecticut Co., New Haven, Conn.

"The large amount of capital involved in a large dam usually results in the employment of a qualified engineer and contractor purely as a matter of insurance; the small dam, however, is often a poor copy, by the cheapest contractor available, of a structure built somewhere else, with little regard to possible differences in conditions, so that the probability of failure in the latter case is much greater than in the former."

A regulatory law should be as broad as possible and should not contain too many specific details. As for building codes, Mr. Harte expressed his opinion that, "the minor details may be covered by the building code, but the major features are special and must be so treated."

The State of Connecticut has a regulatory code dating from 1878. Commenting briefly on this law, Mr. Harte stated,

"It consists of but a few short sections. Since it has been unnecessary to modify it to any material extent, and in that time there have been no failures of moment nor any extended Court actions, although there are very many dams in the State, it may well be claimed that the statutes are satisfactory."

A member of the State Board of Engineers must approve the site, the design, the specifications, and the construction of all dams. Details of procedure and rigid specifications as to strengths of material are not mentioned; the members of the Board are considered qualified to pass on these for any particular case.

Quoting directly,

"By statute one member of the Connecticut State Commission on Rivers, Harbors, and Bridges must be a Civil Engineer. This engineer together with five other engineers from private practice appointed by him, one from each of the five Congressional Districts, constitutes the Board of Civil Engineers having supervision of dams and reservoirs. Each receives $100.00 a year, and in addition $10.00 and all reasonable expenses for each day of actual service.

"In the case of a proposed dam or reservoir, unless it be an ice pond or a fish breeding pond on private land and less than an acre in extent, a member of this Board must inspect the site on the ground, must be furnished copies of the plans, the specifications, and all necessary data, and must grant certificate of sufficiency before work can be begun. He must inspect the work during its construction to the extent necessary to determine if it will be safe and secure, and until he shall have issued a certificate to that effect and it has been recorded in the land records in the town in which the dam is located the structure may not be used. A member can call in for consultation any or all of the other members of the Board to assist him; and the owner may appeal the engineer's decision, first to the full Board and then to any judge of the Superior Court, but these appeals must be taken within 20 days from the date of the decision contested.

"In the case of old structures, on the written application of two or more who would be affected and who claim that there is danger of failure, a member of the Board must inspect the structure in question and if he finds that it is not safe it must be made so, the owner paying all expenses. If, however, it proves safe the expenses of the inspection must be paid by the petitioners. The State's Attorney prosecutes in case of violation of, or refusal to comply with, any orders, and penalties are prescribed.

"The engineer members of the Board are free to carry on their private practice."

In this manner,

"The State has the advantage of the services of men of a calibre for which it could not pay proper compensation if they were full-time State officials, nor could it in propriety ask a properly qualified engineer to serve full time for the salary available if, as then would necessarily be the case, he was debarred from practice in his special field because of his judicial capacity, or as a State officer."

SUPERVISION BY THE STATE ENGINEER

By John P. Hogan,* M. Am. Soc. C. E.

The opinion that regulation of the design and construction of dams should be very broad and should be concerned only with safety, was reiterated by Colonel Hogan. He did not approve the formation of a code as a part of the law. His reason for suggesting the State engineer as the supervising officer was that about 95% of the cases would be perfunctory and only about 5% controversial.

Colonel Hogan emphasized especially the value of insuring the right of direct appeal. Quoting,

"Of course, everybody has the right of appeal to the Courts, but that is a slow and tedious process and one that very few people wish to take. It should be a ready means of appeal. It would seem that that could best be worked out through the appointment by the State and by the owner of a representative and a selection by them of a third representative, the cost of such a matter to be borne equally by the State and the owner, in States like New York that can afford it; in some of the States which cannot, it might be necessary to have a cost assessed against the owner alone. That is, in a case of appeal."

In conclusion, Colonel Hogan recommended that a committee of the Power Division rather than a special committee of the Society would be the best group to propose a form of legislation on this subject.

REGULATION AS INFLUENCED BY COSTS

By Joel D. Justin,† M. Am. Soc. C. E.

Predicting that State supervision of the design and construction of dams will be generally adopted in the future, Mr. Justin stated that,

"Personally, the speaker believes that such supervision is necessary and desirable. On the other hand, it is conceivable that such supervision might lead, in some cases, to unnecessary and unproductive expense or might even so increase the cost of a project that it would have to be abandoned. Again, if the State supervision is merely perfunctory or incompetent, the approval of the project by the State authority would be no index as to its safety."

* (Parsons, Klapp, Brinckerhoff & Douglas), New York, N. Y.
† Hydro-Elec. Engr., United Gas Improvement Co., Philadelphia, Pa.

To add a building code for dams to any law providing regulation would not be desirable because then,

"The State engineering authority would have to certify that the design and construction complied with the code. For the State engineering authority to do this honestly would require nearly as great an expense as that incurred for engineering by the owner. Most, if not all, of this additional expense would almost surely be assessed against the owner."

Mr. Justin approved Mr. Markwart's suggestion to place supervision in the hands of a State engineering authority. This would mean that such authority would have an inspecting engineer on the job throughout the course of construction.

The duties of the inspecting engineer were tentatively defined as follows:

"Such an inspection engineer should have no authority to give instructions, but should report his observations to the State engineer. He should constantly confer with the owner's resident engineer and bring to his attention all cases of faulty workmanship which he notices.

"There are often cases where such State supervision may be of the greatest help to the owner's engineer. Thus, in the case of a project where the financial backing is not of the highest class, the pressure on the owner's engineer to design a cheap structure is often great and difficult for the average man to resist. If, in addition, the owner is also doing the construction, the position of the owner's engineer may prove most unfortunate. Precautions which, to the engineer, are of the greatest importance, often seem foolish and expensive refinements to the uninitiated and may, therefore, in such cases be omitted by the owner's orders. I am referring now to only projects which are conceived by people of small financial importance. In such cases, State supervision proves a veritable Gibraltar of strength to the owner's engineer, enabling him to get a conservatively safe design adopted and constructed with due regard to safety and it also enables him to retain his job."

Commenting finally on appeal provisions, Mr. Justin agreed that an Engineering Board of Appeals would involve less delay than recourse to the Courts.

SIX IMPORTANT POINTS OF EMPHASIS

By Ford Kurtz,* M. Am. Soc. C. E.

The following six statements by Mr. Markwart (with which Mr. Kurtz agreed fully), were discussed:

"1. There is a necessity of introducing greater conservatism and sounder judgment, particularly the latter, in the design and construction of dams.

"2. Critical defects in dams that have failed have been in many cases—I would not say with the author 'almost invariably'—avoidable.

"3. Such avoidable defects can be eliminated almost entirely with effective regulations and control.

"4. With human nature constituted as it is, control from within is not to be expected.

* Hydr. Engr., The J. G. White Eng. Corporation, New York, N. Y.

"5. The value of State supervision will lie only in requiring an independent review of the design, thus insuring the application of more than one mind to the problem. The construction and operation of a great dam should never be left to the judgment of one man, no matter how eminent.

"6. Those in supervisory capacity on behalf of the State Government must obviously be the peers in technical experience and judgment of those engineering, designing, and constructing the dam.

"I believe that Conditions (5) and (6), which are the *sine qua non* of 'effective regulation and control,' can only be taken care of through a permanent commission of competent engineers, not less than six in number, appointed by the Governor and approved by the Senate, the State Engineer to be an *ex-officio* member of the Commission. Decisions should probably require a two-thirds vote, those dissenting being allowed to present minority opinions. All administrative and routine work would be carried out by existing agencies, but the absolute authority would rest with the Commission.

"I wish to emphasize that no useful purpose will be served unless Government brings to the solution of these problems men of skill equal to or greater than the skill of those employed by the owners. Therefore, it is of the utmost importance that the Commission be chosen from competent men active and prominent in their profession. Obviously such men cannot be precluded from practising their specialty in the State which they serve, but I see no reason why they need be. If a judge is interested in a case directly or indirectly, he does not resign from the bench. He simply withdraws from his judicial post as far as that case is concerned. There is no reason at all why a member of the Commission should not act in the same manner when he is interested directly or indirectly in a project before the Commission.

"Of the three features, design, construction, and maintenance, the first and last can without question be handled efficiently by a competent commission. The second feature presents much greater difficulties. It would seem to require at least on major projects, the residence of a Governmental inspector. Construction problems must often be settled quickly. Unless the inspector is a man of qualifications equal to those of the resident engineer and the construction superintendent, his decisions will be of doubtful value. It is difficult to secure such men for Governmental posts. Confessedly, I do not see at this time just how this phase of the problem can be worked out.

"Care must be taken to see that the Commission is not led insiduously into designing the dam. It must pass upon designs only, and, if they are not approved, indicate the general basic reasons of disapproval. Details of methods of correcting disapproved features would be left for the owner's engineer to work out.

"'Effective regulation and control', such as I have briefly outlined, will be valuable to the owner and he should therefore pay for it and pay liberally. Only by payment of adequate compensation to members of the Commission can men of proper skill be induced to accept membership on it. The public should pay something, but certainly not the major portion of the cost.

"As pointed out by the author, appeal to the Courts would always remain as the owner's right. That cannot be taken away from him. It would be his great safeguard against an incompetent or 'political' Commission.

"I do not consider it practical to make an attempt to codify the rules for design, construction, and maintenance of dams.

"I do not wish to minimize the difficulties to be overcome in such a plan as I have suggested, but I do believe it represents the only method of securing results of any value."

PRACTICE IN NEW YORK STATE

By Edward H. Sargent,* M. Am. Soc. C. E.

The New York State Law providing for regulation of the design and construction of dams, dates from 1911. Mr. Sargent felt that its limitation was that dams less than 10 ft. in height, or 1 000 000 gal. in capacity, are exempt. In general, administration of the law has been very good.

Quoting directly,

"The present code requires the submission to the Department of Public Works of plans for dams, giving in detail the design of the dam as well as information regarding foundation conditions during the construction period, and that inspection is quite rigidly carried out by the various district engineers throughout the State."

PRIMARY REQUISITES OF STATE SUPERVISION

By F. W. Scheidenhelm,† M. Am. Soc. C. E.

As to what ought to be done in the matter of State supervision there will naturally be differences of opinion," said Mr. Scheidenhelm, "but minds can presumably meet on the following essentials:

"1.—All dams which through failure or otherwise can affect lives of men or be the cause of damage to property to a substantial extent should, as to their location, design, construction, operation, and maintenance, be under competent engineering supervision.

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"2.—In the cases of important dams, location and design (including the principal specifications as to construction) should be subject to the approval of at least two competent engineers, or engineering organizations.

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"3.—Generally speaking, the design of a dam is not (and sometimes cannot) be completed until the foundation bed is exposed and the foundation is completed.

"4.—The engineers responsible for the approval of the design of a dam should have reasonably close contact with the construction. If they do not have a relationship involving authority with respect to the construction, at least the relationship should be sufficient to allow them to register protests with the owner and any Governmental authority and at the same time to clear themselves of responsibility for the outcome of any given phase of construction as to the performance of which they differ.

"5.—Proper supervision does not end with the completion of construction. It should cover periodic inspection and extend over the entire life of the dam.

"6.—The minimum amount of Governmental supervision should provide adequate administrative machinery and capability as to two things:

"(*a*) The determination whether a given dam is of sufficient importance, from the standpoint of potentialities, to require Governmental supervision.

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* Chf. Engr., Hudson River Regulating Dist., Albany, N. Y.

† Cons. Engr. (Mead & Scheidenhelm), New York, N. Y.

"(*b*) The determination whether competent engineering talent is being brought to bear on the problems of location, design, construction, operation, or maintenance.

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"7. If such administrative machinery and capability and such authority on part of the Governmental supervising agency exist, then the minimum extent of supervision constitutes likewise an adequate extent of supervision."

Commenting on Item 1, Mr. Scheidenhelm explained that, in this case, he had in mind location from the standpoint of safety only. In Item 2 he added the words "or engineering organizations" with some personal skepticism. He admitted that, in the case of Item 7, there might not be as broad an agreement as on the other six items.

Mr. Scheidenhelm approved the idea of a code if it could be solidly founded and correct, but considered it impossible to devise such a code. This difficulty need not hinder the construction of dams, because "safe dams can be built despite differences of opinion."

The cost of supervision, he said, would depend upon the particular State and upon the expedients affecting the particular dam under consideration. In so far as expediency allows it, equity should govern the cost of supervision, according to Mr. Scheidenhelm.

In his opinion it would not be feasible to recommend a uniform law for adoption by all States, because the basic laws of each State differ as well as the machinery used to enforce them.

As regards personal responsibility, he stated that,

"Responsibility for a dam as to its design and construction and limiting that responsibility to the matter of safety should be taken only by a competent engineer. There is not much difficulty in limiting that responsibility to an engineer. The difficulty comes rather in limiting it to a competent engineer.

"I shall not discuss the question as between incompetent and competent engineers, but I do wish to point out that the layman in the matter—in other words, he who has no engineering experience but has a position of Governmental authority—is loath to take any responsibility."

This is illustrated by a quotation from a State law, as follows:

"The Commission is hereby authorized and empowered to exercise in the name of the State through the agency of the Commission, the full police power of the State in so far as the same may be necessary in the matter of safety of dams constructed or operated, partially constructed, or being constructed or operated under the provisions of this act." [That happens to include everything by way of water power]. "In granting licenses and approving plans for dams and other structures to be constructed under the provision of this act, the Commission shall hold the safety of human life of first and highest importance. Provided, however, nothing in this act contained shall involve any personal liability on the part of any member of the Commission or any of its representatives nor create any liability on the part of the State or the Commission for damages resulting from or growing out of the construction, maintenance, or operation of any such dam; and provided, further, that nothing in this act contained shall be construed to exempt or release any licensee from any common law or statutory liability for damages occasioned to the property of others by the construction, maintenance, or operation of such project or project works."

GENERAL DISCUSSION

Law Proposed in England.—Allen Hazen, M. Am. Soc. C. E., began the general discussion by citing features of a law proposed in England in 1928. The idea expressed at that time was for the Government to form panels from which engineers could be drawn who were competent to pass judgment on any particular dam under consideration.

Quoting Mr. Hazen,

"The idea was that different panels might contain the names of men who were qualified for particular kinds or sizes of dams, so that being on a dam panel would not necessarily mean that a man was competent to deal with all dams. To be on this dam panel would be something like being admitted to the Bar, or to some standard of responsibility, and the appointments would be determined by the Government, which, of course, in England can manage things in that way differently from the way they are done in this country. The men on these panels would then be selected by the Government and would be men of great responsibility and capacity.

"The requirement of the bill was that every owner of the dam, before it was built and when it was built, in intervals of five or ten years thereafter, should have an opinion by an engineer on this dam panel, setting forth all information that was necessary, not in previous reports on the same dam, as to its condition, the methods of calculation, what it depended upon to make it stable, and whether the condition of the dam was being maintained. It was the owner's duty to make these reports and to make them public records, to be kept on the works, and open to all comers."

Legal Aspects.—The present law in New York State providing for the supervision of dams, according to J. O. Reynolds, Assoc. M. Am. Soc. C. E., is merely a minor provision whereby supervisors of towns are required to make written reports to the Department of Public Works. Aside from this, Mr. Reynolds stated that,

"I find no other provision of the law, nor do I find that any State authority is required to act or do anything about any such reports made by a supervisor. So in my opinion there is very little, if anything, in the present laws of this State regulating the design or construction of dams."

He raised the question as to whether,

"Some serious consideration of Federal regulation may not be in order. It is true that the Federal Government has no police powers within the States, but by virtue of the provisions with respect to navigable waters it has power over a great number of our streams. The State may permit the construction of works subject to the power of the Federal Government, and of course on our now navigable streams they would have exclusive powers and jurisdiction.

"Many streams are on State boundaries, and where a State authority was provided, or the authority of several States, some conflict might be expected.

"The Federal Government has already various bureaus and scientific organizations which the law provides shall be useful to the Federal Power Commission, so that any regulation by the Federal Government could be supported and assisted by the experts already in the employ of the Government on various phases of the question that would arise—geology, strength of materials, testing of materials, and all such matters."

Commenting on the subject of appeal, Mr. Reynolds agreed that the best provision would be an Engineering Board of Appeals as suggested by Mr. Markwart, because:

"You may hardly expect a Court to substitute its judgment on questions involving technical matters for that of the engineer. The Courts, therefore, should be limited, in my opinion, to a review of the legal phases of this subject. The interpretation of the law, the questions that might arise as to its being carried out on the part of the boards, any question of fairness, capriciousness, or anything of that sort, could well be referred to the Courts, and there need be no special provision, it seems to me, for we already have ample provision for the review of an administrative act."

At present, in California the need is for a regulatory law that will apply alike to private, individual corporations, the State and, if possible, to the United States. L. C. Hill, M. Am. Soc. C. E., stated that,

"The way the State engineer at the present time is handling his particular part of the job is to go over the plans in his office and then call in outside engineers to pass upon not only the plans but also on the foundation, and he is exercising sufficient supervision over the foundation so that he has representatives go there during the time the excavation is going on, and before final approval of the excavation he has a Board that goes out and passes on that.

"One of the difficulties, however, that comes about in all State-supervised operation, is usually that the State department keeps developing more and more a personnel that it wants to keep busy. In one case the State Department actually furnished the design for a dam."

Considerable discussion ensued from various members as to placing a limitation on the sizes of dams subject to regulations. Most discussers differed with the previously expressed opinion that the failure of smaller dams in Northern New England was responsible for much of the damage during the 1927 flood.

STRUCTURAL DIVISION

JANUARY 16, 1930

Morning Session—10:20 A. M. to 12:30 P. M.

PLANS AND RESEARCH—KILL VAN KULL BRIDGE

By O. H. Ammann,* M. Am. Soc. C. E.

Preliminary Studies.—Briefly, Mr. Ammann reviewed the development leading to the construction of various bridges by the Port of New York Authority. Legislation authorizing the Kill van Kull Bridge was passed in 1925 in New Jersey and in 1926 in New York State. Immediately the Port Authority went to work on preliminary studies, including a thorough economic investigation. The upshot of this work was a report to the Legislatures of the two States, supporting the proposed construction both from a financial and an engineering point of view.

The strategic position of this bridge, at the very southern tip of the Bayonne Peninsula, was quite apparent, Mr. Ammann explained, especially in relation to the other important projects between Staten Island and points in New Jersey and the Borough of Brooklyn. In due time the Port Authority was authorized by the two States to build the structure and was given funds for preliminary investigation. Subsequently, the States agreed to advance approximately 20% of the cost of construction. The remaining funds, about $12 000 000 in all, were raised by the sale of Port Authority bonds at an interest rate of 4%, in the fall of 1928. As a result, actual construction has been under way for about a year.

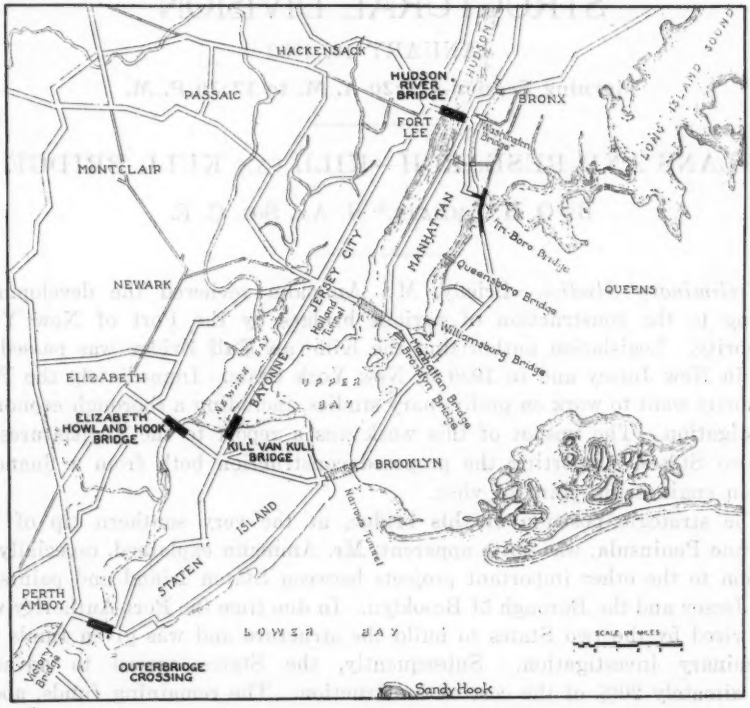
Traffic Demands.—One of the first studies on the Kill van Kull project was based on existing traffic. Due allowance had to be made for the inadequacy of the present transportation facilities. With this in mind and considering the potential factors of the various major highway structures both proposed and built,

"It was found that upon the completion of the bridge, which was expected in 1932, there would be a traffic of approximately a million vehicles a year, and that it would grow very rapidly thereafter, producing sufficient revenue so that at least the interest and the fixed charges in the first year could be covered from revenues, and the entire investment, including the advances made by the States and the interest thereon, could be amortized within from 25 to 30 years."

Assuming that a four-lane highway was provided, this apparently would be adequate for perhaps 20 to 25 years; but it was equally evident, Mr. Ammann stated, that the subsequent capacity would have to be considerably

* Chf. Engr. of Bridges, The Port of New York Authority, New York, N. Y.

greater. Hence, although designed at the present time for a four-lane highway, provision is made "so that it could be widened to 65 ft., providing space for from six to seven lines of vehicles."

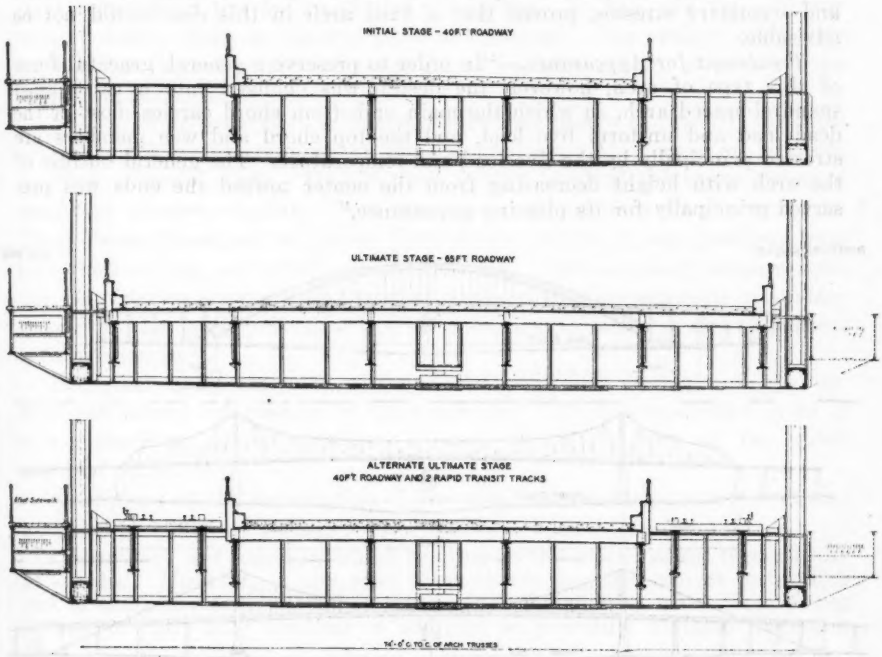


SKETCH OF METROPOLITAN AREA IN VICINITY OF NEW YORK, SHOWING RELATION OF KILL VAN KULL BRIDGE TO OTHER COMMUNICATIONS, BUILT, BUILDING, AND PROJECTED.

An economic study indicated that rapid transit was not warranted from the standpoint of necessary expenditure. The growth of bus transportation, it was felt, would probably give an ample substitute. This view, however, did not find support with transportation interests. Hence, upon the advice of the Transit Commission Engineers and others it was finally decided to allow for two rapid transit tracks at an additional cost of about $1 250 000. The future would then determine whether the tracks or more vehicular traffic lanes should be added.

The Kill van Kull Bridge throughout its length is uniformly about 1 200 ft. wide, so that no particular location was preferable from the standpoint of span alone. Instead, geographical considerations governed the site. As a result, the bridge is being built on a considerable skew and the resulting span is 1 675 ft. Approaches at 4% grades lead directly to the Hudson Boulevard on the north and to traffic arteries in the Town of Port Richmond on the south. A considerable area of unimproved land on Staten Island will form

a most convenient and economical position for an extensive plaza at the end of the south approach. Thence, traffic arteries of major character will provide immediate connection to important adjacent points.


INITIAL STAGE - 40FT ROADWAY
ULTIMATE STAGE - 65FT ROADWAY
ALTERNATE ULTIMATE STAGE
40FT ROADWAY AND 2 RAPID TRANSIT TRACKS

KILL VAN KULL BRIDGE: TYPICAL CROSS-SECTIONS OF ARCH SPAN.

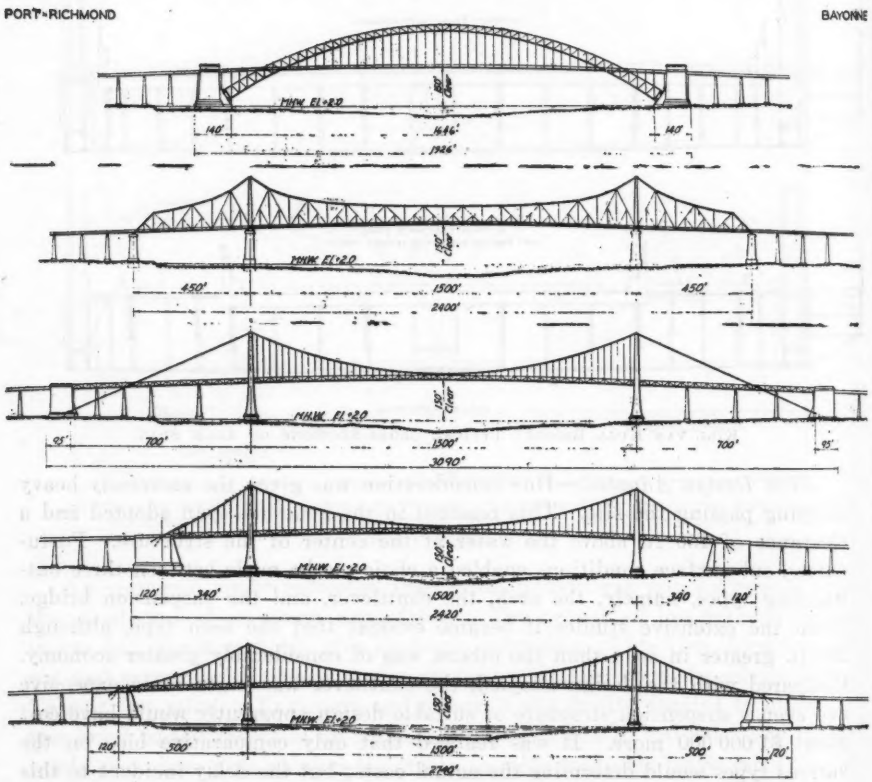
Arch Design Adopted.—Due consideration was given the extremely heavy shipping passing the site. This resulted in the generous span adopted and a clearance of 150 ft. above the water at the center of the structure. Fortunately, sub-surface conditions enabled a choice to be made between three outstanding types, namely, the arch, the cantilever, and the suspension bridge. From the extensive studies it became evident that the arch type, although 200 ft. greater in span than the others, was of considerably greater economy. Compared with the design adopted, the cantilever was much more expensive and even a suspension structure of suitable design apparently would have cost about $1 000 000 more. It was realized that only comparative bids on the various types would determine the actual costs; but the delay incident to this determination was most undesirable, hence the decision in favor of the arch design.

There followed an intensive study as to what particular type of arch should be constructed. As Mr. Ammann explained,

"In the first tentative design, the two-hinged arch of the so-called crescent shape was selected and was thought to offer merits. However, on further detailed studies it was found that the end hinges would offer considerable difficulties, and also the shape of the arch did not seem to satisfy entirely

on account of its greater height at the center as compared with the ends. A study made of a hingeless arch also indicated that there might be a considerable economy on account of the effect of the fixity at the ends. However, further studies, and particularly the determination of the stresses for wind and secondary stresses, proved that a fixed arch in this case would not be advisable.

Treatment for Appearance.—"In order to preserve a general, graceful form of this type of arch, however, the design was changed into a two-hinged spandrel-braced arch, in which the main or bottom chord carries most of the dead load and uniform live load, and the top chord and web members are stressed principally by the live load and temperature. The general outline of the arch with height decreasing from the center toward the ends was preserved principally for its pleasing appearance."



KILL VAN KULL BRIDGE: COMPARATIVE DESIGNS.

Also, for the sake of appearance, massive looking granite-faced concrete abutments were provided. In reality, however, these are but hollow structures with a steel framework carrying the floor above. Below the skewback the abutment is of solid concrete construction extending down to bed-rock, that is, for about 10 ft. below water on the New Jersey side and 25 to 30 ft. on the Staten Island side.

In all, with the approaches, the structure is almost 9 000 ft. long. The expense for extra provisions for traffic on the main structure demanded a rigid economy in the design of the approaches. To this end the ordinary type of deck girders on concrete piers was adopted. The viaduct piers were made hollow in order that their size might be large enough to give a more massive appearance.

Special Investigations.—As finally adopted the design of the Kill van Kull arch involved no outstanding or unusual problem. Its very size, however, justified a careful study. One of these studies involved the computation of secondary stresses resulting from the riveted connections of the members. These "were found not to exceed 1 500 lb. per sq. in. in any member, from both the live load and wind stresses combined. The secondary stresses from the pin friction at the ends, tend to produce very considerable secondary stresses in the end members, and it was necessary to reinforce those members correspondingly."

A further study was made of the secondary stresses arising from the vertical and lateral deformation of the structure. This also was found to be of minor character, giving maximum stresses of 1 500 lb. per sq. in., which could be neglected.

Conditions at the intersection of the arch and the floor system were also a subject of study. Finally, .

"A solution was found by which bending in the chords might theoretically be avoided. However, in any case, these chords must be subject to bending and to secondary stresses, and it was decided therefore to make them strong enough to carry that bending in addition to providing indirect transverse shear."

Design of Hangers.—The proportioning of the hangers which carry the suspended floor from the arches appears to be a very simple matter; but it proved "to be one of the most intricate problems connected with the design of the bridge." The difficulty arose from the fact that these members are subjected to intense bending longitudinally and laterally on account of wind and temperature. Furthermore, vibration either from wind or movement of the floor is an important consideration. Because of the various uncertainties as applied to built-up sections of steel, it was finally decided to use twisted wire rope.

An objection to ropes, Mr. Ammann mentioned,

"Is that they are flexible longitudinally and it might lead to vibration of the floor vertically. To guard against this, it was decided to design those ropes of a high modulus of elasticity and use a comparatively high sectional area, that is, to reduce the actual stresses to very considerably below what might be admissible for strength."

Model Tests Found Invaluable.—Having made all these careful studies, it was further decided to corroborate the findings if possible by an extensive series of model tests, especially to determine the efficiency of the provisions at the intersections of arch and floor and also the effect of sway-bracing. Speaking in general terms, Mr. Ammann reported that:

"The results from the model tests have been beyond expectation. In the first place, the stresses determined by measurements, at least where the condi-

tions corresponded to those upon which the calculations were based, agreed very remarkably with the calculated stresses.

"The model also proved the efficiency of the design at its intersection with the floor. It proved the remarkable stiffening effect of the sway-bracing at the end, and it also indicated that the sway-bracing in the middle portion was of very little value and therefore could be omitted."

Based on these observations, Mr. Ammann concluded that stresses obtained from such models may in some cases be more reliable than those calculated. In fact, "no amount of calculation could give such an insight into the stressed condition of the structure". As a further safeguard, stress measurements on the actual structure before and after completion will be carried on in considerable detail. In particular, the structure will offer exceptional opportunities to study the action in built-up members and valuable results are expected from this source.

Economy of Special Steels.—As a matter of economy, certain parts were designed to be built of silicon, instead of carbon, steel. It further appeared that even higher grade material, for example, nickel steel, could be used with a saving on some of the members, as, for instance, the bottom chords of the arch.

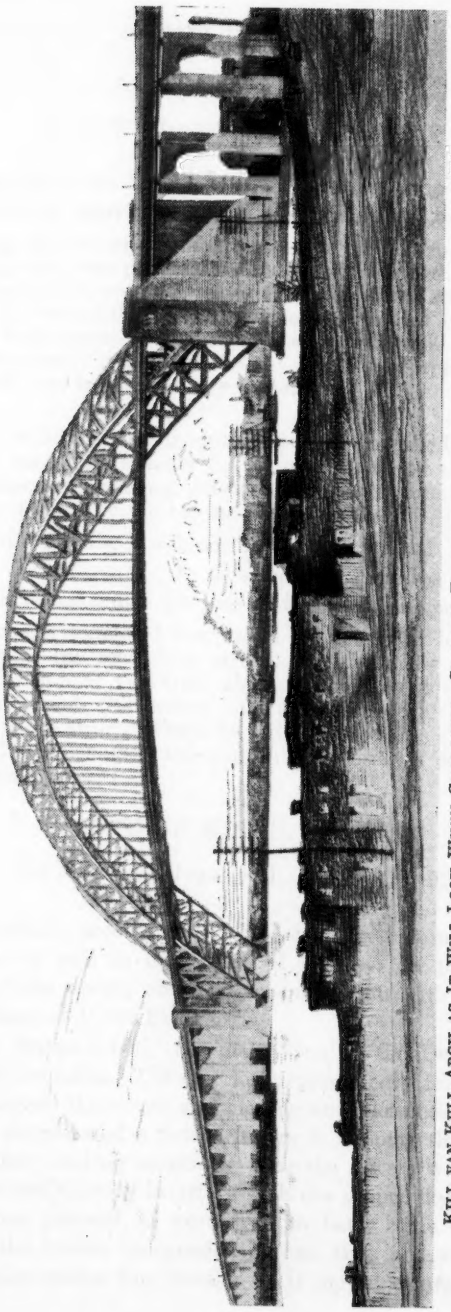
The contractor, the American Bridge Company, offered to substitute a carbon-manganese steel for the nickel steel specified. After a complete investigation this was done and subsequent tests have shown that the material gives an ultimate stress of more than 90 000 lb. per sq. in and a yield point of more than 55 000 lb. In addition, large sized compression tests have shown the value of the material in such members as the bottom chords of the arch.

As indicating the magnitude of the structures affected, Mr. Ammann called attention to the sizes involved in two of the large bridges being built by the Port of New York Authority. Actually, the columns of the Hudson River Bridge will have an area of more than 1 300 sq. in. of silicon steel; the larger sections of the Kill van Kull Arch will be about 1 000 sq. in., being composed of manganese steel. Because of limitations in the capacity of the testing machine the test specimens were made to about one-half the dimensional size and about one-quarter of the sectional area of the material in the structure. The resulting sizes of the test structures were therefore about 159 and 155 sq. in., respectively.

Practical Limitations.—In conclusion, Mr. Ammann called particular attention,

"To the conditions under which this project had to be planned and carried out. The Port Authority is a public body. It received direct from the States a mandate to build this bridge and in that respect it had to go as far as possible to meet the interests of the public in so far as the safety of the structure is concerned, in respect to possible future increase in traffic, in respect to meeting the wishes of the various municipalities for highway connections, and also in meeting the wishes of navigation, such as for clearance over the river.

"On the other hand the Port Authority is in a position very similar to that of a private concern in that it has to build the structures on a financially sound basis. Once securities were issued to the bondholders, it had to keep the expenses within the funds provided."



KILL VAN KULL ARCH AS IT WILL LOOK WHEN COMPLETED, SHOWING TREATMENT OF ABUTMENTS AND VIADUCT APPROACHES.

DISCUSSION

A CAREFUL DESIGN

By C. W. Hudson,* M. Am. Soc. C. E.

Certain intangibles are bound to enter into the proper design of such a monumental structure, according to Professor Hudson. For example,

"In appraising the elements which are really the determining elements of a structure, the engineer has no definite and fixed standard, certainly not from a value in dollars, as, for example, of the stiffness of the structure, the relative permanence of the material, the relative permanence of each of the designs, and the relative appearance of the three designs selected. The speaker is inclined to lend very great importance to the element of appearance and to feel that its value in dollars is rarely appreciated."

* * * * * *

"Until a steel with a higher modulus has been invented than that of structural steels now used, the speaker is inclined to favor the steel giving the greatest cross-section of member, other things being equal; but just to what extent such favor should go, he has no definite guide."

Speaking of the details, Professor Hudson expressed appreciation of the careful study of the structure. In this, he also included the general design, dimensions, and arrangement. The use of the model, he thought,

"Could be properly extended too, and I do not know but this was considered in determining the secondary stress; that is, there would be a considerable lateral deflection of the arch, also a displacement of the dead load of the arch with respect to its center line and, therefore, an increase in the stress of members. I think it would be quite appreciable on some large cantilevers on which I have made a calculation and found a considerable load on the leeward trusses."

VALUE OF MODEL STUDIES

By Jonathan Jones,† M. Am. Soc. C. E.

Engineering models, according to Mr. Jones, are coming into use to solve erection problems as well as difficulties of design. In particular, he mentioned certain notable results obtained in connection with the Detroit River Bridge and the Maumee River Bridge.

Detroit River Bridge.—Only the main span of the Detroit River Bridge is suspended from the cable. The erection program calls for a traveler moving from the towers toward the center and placing only the floor-beams, the stiffening truss bottom chords, and a few stringers to support the traveler. It was seen that incomplete loading especially near the towers would cause a sharp kink in the cables and thereby interfere with the proper floor connections.

It was therefore planned, if necessary, to hang some of the floor-beams in the center of the bridge independently, and thus add sufficient weight to reduce the deflection under the traveler as it moved outward. According to Mr. Jones,

* Cons. Engr.; Pres., C. W. Hudson, Inc., New York, N. Y.
† Chf. Engr., McClintic-Marshall Co., Pittsburgh, Pa.

"The calculations were reduced to a check on the simplest of all the cases to compute, that of complete loading, with which the results from the model could be compared for that same condition. For all other cases, *i. e.*, those of incomplete loading, the results from the model were much more quickly obtained and with the necessary degree of accuracy."

Maumee River Bridge.—In this bridge the main cables are relatively light, being, in fact, only 12 in. in diameter. In comparison the stiffening girders are quite heavy so that the resulting distortion might require considerable study of erection problems.

During the time required to construct the model—a period of about one month—it would have been possible for a computer to have completed the study of about four erection conditions. After that, however, two men could easily test and record complete deformations of any given condition in the space of about one-half hour. In the aggregate, therefore, the result of the use of the model was a great economy of time and, at the same time, a great extension in the field of study. Thus, Mr. Jones pointed out, the model was able to determine:

> "1.—The roll of the saddles back and forth on the tower tops under various erection stages; hence the necessary details to be provided to permit of these movements.
>
> "2.—The stage of erection, *i. e.*, the precedence of main span erection over side span erection, at which the side span cables will be picked out of certain temporary supports required during their spinning.
>
> "3.—The practicable lengths of stiffening girders to be erected without too great distortion of cables or too great difficulty in making connections. In a word, the model has determined that at mid-span where erection commences, the field splices must be only 20 ft. apart; and that at the towers or approaches the shop length may be increased to 40 ft. with resulting speed and economy.
>
> "4.—The vertical angles between adjacent lengths of stiffening girder during successive erection conditions, to and including the process of pouring the roadway concrete slab; and the times at which the field riveting of the girder splices may be undertaken."

These experiences led Mr. Jones to conclude that, in general, computations are not necessary and should be used only for the simplest cases. Discrepancies between the two methods are not of serious moment; in fact, in all probability the differences are not "as great as the actual differences between either set of results and the actual results in the field".

In the future, he looks for even more accurate methods of testing by model so that they may be actually used for designing structures, giving both stresses and deflections.

ALTERNATIVE SUSPENSION DESIGN

By Leon S. Moisseiff,* M. Am. Soc. C. E.

Commenting on the comparisons made to determine the desirable type of bridge for this location, Mr. Moisseiff considered that most engineers would

* Cons. Engr., New York, N. Y.

agree with the final decision. He contended, however, "that this 1 500-ft. bridge has been loaded to 7 000 lb. per lin. ft., and that it is possible to build a suspension bridge that would be cheaper than the one that has been recommended."

Tests of the model were most useful, Mr. Moisseiff believes, especially in determining the effect of vertical loading on the arches. According to him, "secondary stresses have come into a certain amount of disrepute. They are neglected; and there is a very well-founded notion that they are helpful". The value of the model, he feels, lies largely in determining these points.

With respect to the vertical loading shown by the tests, he was most surprised to learn that for a loading that is eccentric laterally the far chord participates almost as much as the near chord in carrying the weight. He was also interested in the test results showing the necessity of sway-bracing near the hinges, but the uselessness of such bracing in the center of the arch. This, he thought, showed one great advantage of the arch, that it is stiffer than the suspension type. All in all, Mr. Moisseiff concluded, the provisions for such extensive tests indicated great foresight on the part of the Port Authority and its engineers. Other organizations may well follow this good example.

ADVANTAGES OF A CONTINUOUS BRIDGE

By C. M. Spofford,* M. Am. Soc. C. E.

The choice of an arch type was largely dictated, according to Professor Spofford, by the ideal sub-surface conditions at the site. The foundations were relatively inexpensive and yet were admirably secure.

Without attempting to compare the various types originally investigated, Professor Spofford was inclined to think that it would have been well to consider the possibility of a continuous structure instead of the cantilever type. He stressed the fact that no economic superiority was urged as against the arch type, but simply by comparison with the cantilever. These advantages he summed up as follows:

"A continuous bridge has certain advantages over a cantilever bridge, particularly where rock foundations prevent any uncertainty in stresses from unequal settlement, although a moderate amount of settlement in a continuous bridge foundation usually affects only the dead stresses due to the weight of the steel superstructure, and influences these much less seriously than some engineers seem to believe. Moreover, a continuous bridge for the conditions existing at this site can, in the speaker's judgment, be made nearly as pleasing in appearance as an arch bridge. Such a bridge has advantages over the arch bridge in the practical elimination of temperature stresses as well as of the long hangers. These of themselves add much to the weight of the structure and offer certain difficulties in design, as evidenced by their failure in a recently constructed bridge.

"Other advantages * * * are the fact that the bottom chord bracing may be made continuous and that the top chord bracing may be omitted over the intermediate piers where the top chord is in tension, since wind forces on

* Hayward Prof. of Civ. Eng., Mass. Inst. Tech., Cambridge; Cons. Engr. (Fay, Spofford & Thorndike), Boston, Mass.

it can be readily carried to the continuous bottom chord by cross-frames. Moreover, the structure is not so high as an arch, and, therefore, not subject to as severe an overturning force due to wind. Also, the erection of the main span, either as a cantilever or continuous bridge, can be advantageously accomplished without the use of falsework or, if it seems advantageous, with a small amount of falsework at either pier.

"As compared with a cantilever bridge, the continuous structure has advantages in erection and fewer expansion joints which are always disadvantageous in highway bridges."

Value of New Steels.—It was fortunate, continued Professor Spofford, that the magnitude of this work and the funds available, warranted the extensive research accomplished. In particular, he expressed interest in the new high capacity steels. Provided these show in practice what they seem to promise in tests, they should point to economies in structural design especially as applied to long span structures in which the dead weight is of greatest importance. He pointed out, however, that they will involve greater distortions and deformations and, accompanying these, greater secondary stresses. If only the modulus of elasticity could be increased proportionately, this disadvantage would be obviated. Perhaps modern methods of making steel will accomplish this.

Other possibilities of note he found in the use of manganese steel for rivets. This would tend to reduce not only the number of rivets, but the size of connections. In common with the other discussers he commended the extended investigations, especially those of secondary stresses.

POSSIBILITIES OF MODEL TESTING

By C. E. Chase,* M. Am. Soc. C. E.

Other things beside mere cost must enter into the final decision as to the structure to be built, according to Mr. Chase. As he expressed it:

"That does not mean that the dollars and cents are not an element of major importance. But to admit the fact that the best estimator is not able to approximate the actual difference that would be found by bids is to say that after all, when you get within a matter of 10 or 15% in your balance, the rest of the decision must depend upon the nature of the work to be done, and of the public demand. It is an admission of the fact that in our present civilization, we must, in structures of major importance express in some way the development of our American civilization."

The young engineer should not feel that models are going to do away entirely with the need of scientific study and calculations. Of itself, turning a crank will never design bridges. However, the designer probably will,

"Appreciate the greater scope that is given to the imagination by study of a model in setting up certain major, and less easily anticipated, actions of the bridge, leaving the designer free to make a proper interpretation of the analysis of the structure on the basis of what he had seen in the model."

* Cons. Engr., Philadelphia, Pa.

Even in elementary problems, the model will find its proper place. For example, its study "would lead us to appreciate how little we understand the action of a simple truss, the action of sway-bracing, laterals, etc."

As regards the new material, carbon-manganese steel, Mr. Chase expressed his interest in its behavior under actual use. Its performance in the shop as well as in the structure itself will be of great interest. Furthermore, it will be essential to know in detail of its behavior under tension as well as compression.

ART IN LARGE BRIDGES

By Charles Evan Fowler,* M. Am. Soc. C. E.

In a written discussion, Mr. Fowler expressed extreme regret that lack of funds had made it necessary to omit decoration of the Kill van Kull Arch; this he termed, "a great misfortune".

He has found a marked unanimity of opinion throughout the world in engineering circles tending toward an artistic treatment of structures. On the Continent this is quite marked. By referring to England, a single instance illustrates this fact, namely, a student prize inaugurated by the Institution of Civil Engineers in London. In America, besides the prizes offered by the Society, there is one furnished by the American Institute of Steel Construction to be awarded yearly for the most beautiful steel bridge.

Much regret must be felt, stated Mr. Fowler,

"That money was not available to construct the Kill van Kull Bridge with the beautiful arched approaches and with adequate towers such as are a very great artistic asset to the Hell Gate Arch. It is not disclosed from the present data, as to whether these towers can be added to the abutments in the future, but many will hope that they will be completed in the early years to come."

Ordinary experience with engineering structures, however, does not give much hope for a beautifying in the future, as is shown by the incompleted towers of the Brooklyn Bridge.

A study of examples of arches has shown that there are eighteen distinct types architecturally. For elemental beauty the first place should go to a structure with latticed ribs and no hinges. The Kill van Kull type is third on the list in order of beauty. Mr. Fowler referred to a design for a Hudson River bridge having an arch span of 2 850 ft., with two flanking arches, each of about 750 ft. span. This structure, proposed by Mr. A. M. Ende, "formed a most imposing, monumental, and beautiful design and is sufficient answer to those who contend that great size in a bridge produces a majesty of appearance which renders real beauty unnecessary".

For use in the chord members of such tremendous bridges, Mr. Fowler recommended the cellular octagonal type. In one design for an arch of 1650-ft. span it was proposed to use such chords about 8 ft. 4 in. in diameter. This form "is believed to be the most economical section which can be fabri-

* Cons. Engr., New York, N. Y.

cated from drawings in the bridge shop". In addition, it provides a suitable connection for web members and transverse bracing.

Although he has been somewhat partial to the possible use of silicon steel, Mr. Fowler gladly accorded to the new manganese steel great possibilities in future use. The program developed and the results so far obtained are most fortunate and should yield exceptional information in advances in the art of bridge building.

CLOSING DISCUSSION

In turn, Mr. Ammann took up various questions that had been raised by different discussers during the meeting. A brief study had shown that the continuous truss "would have no economic merit whatsoever." Had there been any latitude as to length of spans and position of piers, the continuous structure might have shown possible economy. At this location, however, the side spans would have been unduly large and the bridge would have been a cantilever to all intent, except for its effect on the live load, which is less important than the dead load.

As to the chemical contents of manganese steel, Mr. Ammann quoted the maximum percentages as 0.40% for carbon and 1.8% for manganese. Regarding a question as to whether steel towers could have been used instead of masonry, he believed that considerations of appearance demanded the concrete structure, faced with granite.

Another question involved the use of eye-bars for hangers. This form was considered:

"But it was thought that secondary stresses in eye-bars would be quite large; that they did not offer the versatility desired; and that, therefore, the twisted wire rope was preferable."

Afternoon Session—2:30 P. M. to 5:00 P. M.

Further consideration of the Kill van Kull Bridge was devoted to questions of design and erection as described by Allston Dana, M. Am. Soc. C. E. Moving pictures of several of the interesting features were then shown. These cannot be reproduced; instead, Mr. Dana's own condensed description will give a good idea of the entire subject.

DESIGN AND ERECTION—KILL VAN KULL ARCH

By Allston Dana,* M. Am. Soc. C. E.

General Description.—The Kill van Kull Bridge spans the river with a two-hinged steel arch, 1 675 ft. long between bearings, and 1 652 ft. long

* Engr. of Design, The Port of New York Authority, New York, N. Y.

between the end pins. The main ribs of the arch form a parabolic curve with a rise of 266 ft. They constitute the lower chords of the arch trusses, the upper chords and web members of which carry a relatively small proportion of the dead load. The two arch trusses are 74 ft. apart. They are 37½ ft. deep at the center, and 67½ ft. deep at the ends, and are divided into forty panels about 41 ft. long.

Load Conditions.—The arch has been designed for two alternate final conditions of dead load and live load. The initial construction of the floor will provide for a 40-ft. roadway. On each side, space is provided for the later addition of a rapid transit track, or for the later widening of the roadway. Both the dead load and live load are different for these two final conditions. If the two tracks are constructed the dead load will be 6% less, but the live load will be 50% greater than if the roadway is widened.

Stresses in all members have been calculated for dead load, live load, impact, temperature, and wind load, and the following combinations have been used in proportioning the members:

A.—Dead load, live load, impact, and temperature.
B.—Dead load, temperature, and wind load.
C.—Dead load, live load, impact, temperature, and one-half wind load.
E.—Dead load, one-half live load and impact, temperature and wind load.

For Combinations *C* and *E* an increase of 10% in the unit stresses has been permitted.

In calculating the stresses the arch was assumed to be three-hinged with a hinge at *L*-20 for the dead weight of the arch itself, while for the balance of the dead load and for live load, impact, temperature, and wind load, the arch was assumed to be two-hinged.

Wind-Bracing Systems.—The wind bracing of the floor system for the twenty-four center panels acts as a simple lateral span with hinges at its ends. Between each hinge point and the point where the wind chord intersects the lower chord of the arch the floor wind system acts as a cantilever arm. From this intersection point to the end of the span the wind shear from the suspended floor is transmitted to the abutments through the bracing in the plane of the lower chords.

The wind bracing in the plane of the lower chord forms a lateral truss with fixed ends at the abutments. The bracing, however, is interrupted for two panels where the floor passes through the plane of the chords. Portal bracing is provided for two-thirds the length of the upper panel, the wind shear being carried by this portal and by transverse bending in the chords. In the lower panel there is no bracing at all, but the short hangers at its upper end are made heavy, and serve to carry the shear down to the floor system, the lower chord wind shear being carried by the floor-bracing for this panel.

In the plane of the upper chords there is a similar system of wind bracing, with portals and unbraced panels, the wind shear being carried by the floor-bracing for one panel. Part of the wind shear is carried to the abutment by the end sway frame, and part by the other sway frames below the floor and by the lower chord bracing.

In designing the wind systems various alternate paths for the wind shears were assumed to be acting, the relative stiffness of the various paths was calculated, and the proportion of the shears carried by each path was determined. The stiffest paths were then made strong enough to carry the whole amount.

Grades of Steel.—Three grades of steel are used in the arch, more or less arbitrarily called carbon steel, silicon steel, and manganese steel. The specified minimum yield point and the allowable unit stresses in tension and compression for each of the three grades are given in the following tabulation.

PHYSICAL QUALITIES OF STEELS, IN POUNDS PER SQUARE INCH.

Grade.	Yield point.	Tension.	Compression.
Carbon steel	35 000	20 000	17 000
Silicon steel	45 000	27 000	23 000
Manganese steel	55 000	33 000	28 000

From a comparison between the strength of each grade of steel and its assumed cost per pound it was found that silicon steel, dollar for dollar, was stronger than either carbon steel or manganese steel. Consequently, silicon steel was used generally throughout the structure wherever the sizes of the members were determined by the strength required. Carbon steel was used where stiffness rather than strength was required or where the size could not be reduced by the use of a stronger grade of steel. When determining on the grade of steel for the lower chords, however, another factor entered. The weight of the lower chords constitutes a considerable percentage of the total dead weight of the bridge. Consequently, the use in these chords of a higher grade of steel than silicon steel, although it might cost more per unit of strength, reduced the dead load, and, therefore, the stresses, to such an extent as to be justified economically.

As a result of these considerations, the main material for the lower chord was designed of manganese steel throughout; the main material for the top chord was designed of silicon steel, except in the three end panels, which are made of carbon steel; and the web members were designed of carbon steel throughout. Carbon steel is also used in all the bracing. Although it would have been cheaper to have used silicon steel members of the same strength for much of the bracing, it was decided that the greater stiffness resulting from the use of the heavier carbon steel members was desirable.

Type of Sections.—The chord members are made with cover-plates both top and bottom, the lower chord having in addition a transverse web at its center. The web members are made with lacing in the transverse planes. The cross-section area of the lower chord varies from 980 sq. in. at the end to 583 sq. in. at the center.

Provision for Erection Stresses.—In the design prepared by the Port Authority and given on the contract drawings the members of the arch trusses were proportioned for the final stresses only and the contract provided that

KILL VAN KULL BRIDGE: COMPOSITE ELEVATION TO ILLUSTRATE ERECTION METHODS (SUPPORTS, SHOWN DOTTED, USED AT EARLIER STAGES); ALSO, TYPICAL CROSS-SECTIONS OF CHORD MEMBERS.

wherever the method of erection made necessary an increase in the strength of any members such changes were to be made at the contractor's expense, or, in other words, that the increase in cost due to such changes was to be covered by the unit prices of the bid applied to the weight and grade of steel of each member as originally designed. This arrangement was decided on because it was impracticable to predetermine the method of erection and make definite provision for erection stresses in the original design, and because it was desired to favor that method of erection which was really the most economical, including the cost of providing for erection stresses.

The center line of the channel, which was required by the War Department to be kept open for navigation unobstructed by erection bents, was located considerably south of the center of the span. This meant an unsymmetrical arrangement of erection bents and made uncertain the point at which the two cantilever operations should meet.

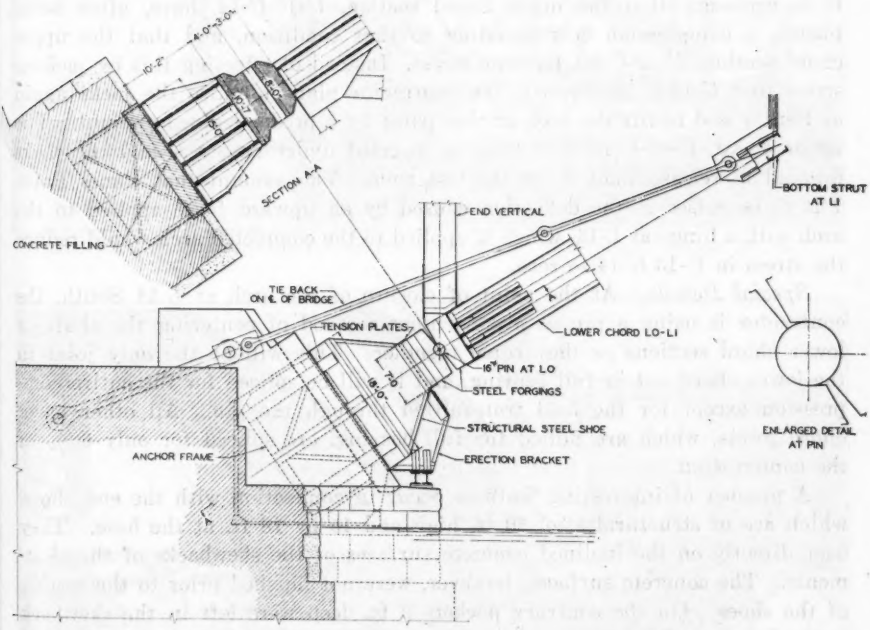
Erection Program.—The contractor's program of erection of the arch is to cantilever successively from temporary bents located at Panel Points 1, 2, 4, and 7, on the south side, and at Panel Points 1, 2, 4, 7, 11, and 16, on the north side, the two operations meeting at Panel Point 14 on the south side where closure is to be made. At the time of closing, the cantilever arm and the anchor arm on the south side will each be seven panels, or 289 ft. long. On the north side the cantilever arm will be ten panels, or 413 ft. long, and the anchor arm will be sixteen panels, or 661 ft. long. The erection of the south portion is to be completed before the erection of the north part is started. The erection traveler, which runs on the upper chord, after erecting the south side to Panel Point 14 will back off, erecting the part of the floor above the arch as it goes, and will then be taken down and moved over to the north side. After erecting the north portion the traveler will proceed forward to Panel Point 7 on the south side and will then back off to the north, erecting the hangers and heavier floor sections as it goes.

This erection scheme made it necessary to strengthen part of the upper chord and some of the web members, either by increasing the sectional area, or by using a higher grade of steel, or both, but no strengthening of the lower chord was required.

Erection Bents.—To a very considerable extent permanent members of the bridge are being used temporarily in the erection bents. For instance, twenty of the main span floor-beams and eight of the main girders of the south approach, temporarily latticed together in pairs, form the columns for the larger bents. One set of these floor-beams is used in Bent 4 on the south side, taken down, and used again in Bent 4 on the north side, and again taken down and used for a third time with two additional sets of floor-beams in Bent 11 on the north side, the three sets of floor-beams being set up end to end. Two other sets of floor-beams are used end to end at Bent 7 on the south side. At Bent 7 on the north side a set of approach girders is used which is taken down and used again at Bent 16, with an additional set of approach girders. These floor-beams and girders are being made with special ends to connect to the shoes at the top and bottom of the bents. The cover-plates on the floor-beams have been increased slightly as to thickness,

and have all been extended to the full length. For the bents at Panel Points 1 and 2 and for some of the bracing in the bents other members of the permanent structure are used, such as diagonals and laterals.

In the transverse bracing of the erection bents, eye-bars are used for the diagonals. In order to make this bracing more effective some of the horizontal members are made adjustable and provided with jacks so that after the bents are erected the whole bracing system can be pre-stressed, the eye-bars being put into tension. This will be sufficient not only to prevent the loosening of the eye-bars due to the compression in the columns of the bent when under load, but to obtain the additional stiffness of a double system of diagonals, by keeping both diagonals in action, for at least part of the wind load.



KILL VAN KULL BRIDGE: DETAIL AT ABUTMENT.

The foundations for the erection bents consist of steel boxes sunk to rock and braced together, in which, in the case of Bents 1, 2, and 4, square timber piles, packed close together, are driven to rock, and in which, in the case of Bents 7, 11, and 16, steel beams are sunk to rock and the spaces between filled with concrete.

Jacking.—As the cantilever erection progresses each bent will be released from load after the arch has been landed on the bent beyond. The transfer of load from one bent to the other will be effected by jacking, but jacks are provided for this purpose at alternate bents only. On the south side the jacks at the bottom of Bent 2 will be raised to transfer the load to that bent and to release Bent 1. Later, those jacks will be lowered to transfer

the load to Bent 4 and to release Bent 2. Jacks at the top of Bent 7 will be raised to transfer the load to that bent and to release Bent 4.

The same procedure will be followed on the north side, the jacks at Bent 7 then being lowered to transfer the load to Bent 11 and to release Bent 7. Jacks at the top of Bent 16 will be raised to transfer the load to that bent and to release Bent 11. When the cantilever erection has been completed the jacks at Bent 7 on the south side and at Bent 16 on the north side will be lowered to effect the closing of the arch at Panel Point *L*-14 South and to release those bents.

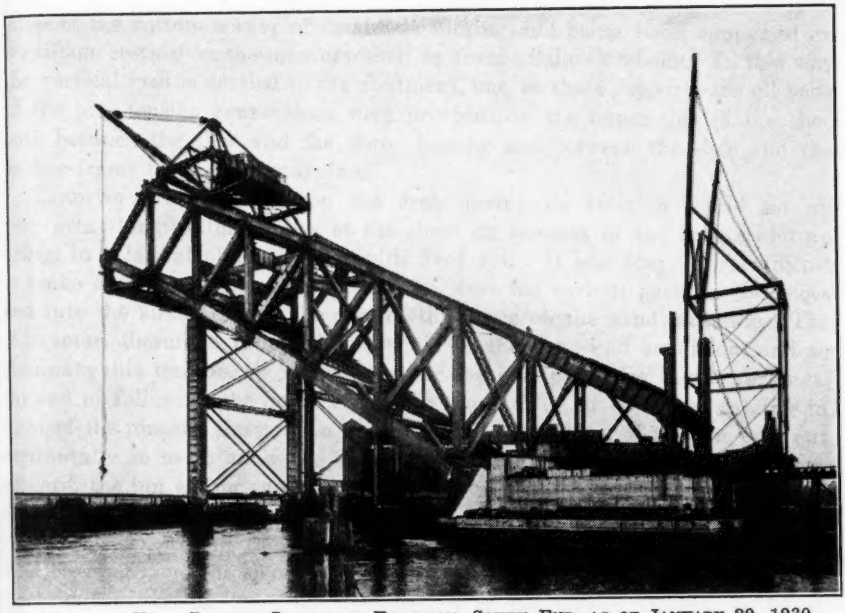
After the arch is swung with the upper chord section, *U*-13-*U*-14, not in place, there will be a condition of three-hinged arch with a hinge at *L*-14. In order to change this to a three-hinged condition with a hinge at *L*-20 it is necessary that the upper chord section, *U*-13-*U*-14, have, after being placed, a compression corresponding to that condition, and that the upper chord section, *U*-19-*U*-20, have no stress. Instead of effecting this by jacking stress into *U*-13-*U*-14 directly, the contractor plans to raise the jacks again at Bent 7 and to lift the arch at that point by a predetermined amount. The upper chord, *U*-13-*U*-14, will then be inserted under no stress and the jacks lowered to release Bent 7 for the last time. The amount that Panel Point 7 is to be raised is the deflection caused by an upward force applied to the arch with a hinge at *L*-14, which if applied to the completed arch would reduce the stress in *U*-13-*U*-14 to zero.

Special Details.—At the point of closure of the arch at *L*-14 South, the contractor is using a pin as a convenient method of centering the abutting lower chord sections as they come together. This will be the only joint in the lower chord not in full bearing, and it will be spliced for the entire compression except for the load transmitted through the pin. All other lower chord joints, which are milled for full bearing, are spliced for only 60% of the compression.

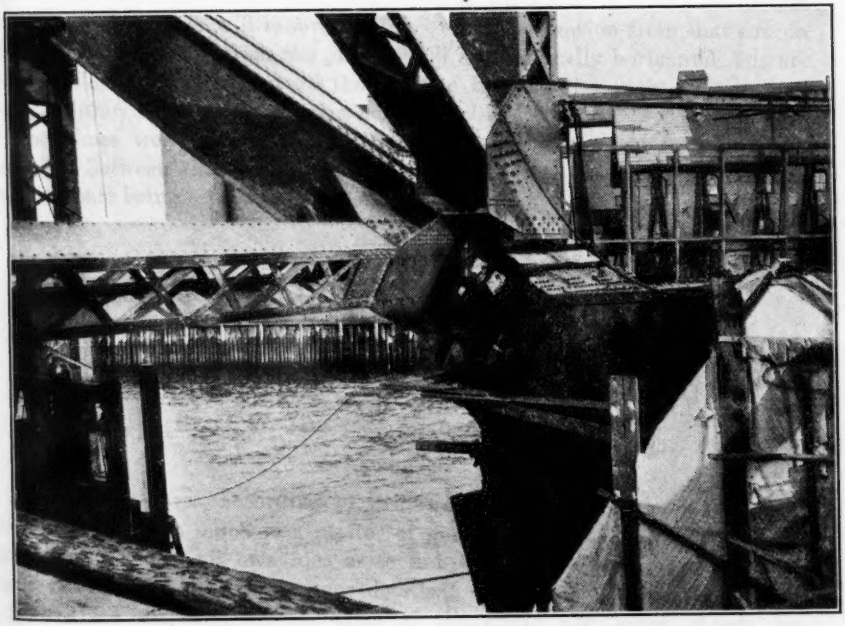
A number of interesting features occur in connection with the end shoes, which are of structural steel 10 ft. high and 15 by 18 ft. at the base. They bear directly on the inclined concrete surfaces of the skewbacks of the abutments. The concrete surfaces, however, were not finished prior to the setting of the shoes. On the contrary pockets 2 ft. deep were left in the skewback at the location of the shoes and structural steel anchor-frames were embedded, projecting through the pockets to the face of the skewbacks. The shoes are erected on the projecting edges of these frames and shimmed to correct position. The pockets back of the shoes are then filled with concrete.

Between the top of the shoe and the end of the first section of the lower chord there are a pair of heavy steel forgings with a 16-in. pin between them, the total depth of the two forgings being 7 ft. The upper forging distributes the load along the pin and to the various webs of the chord section. The lower forging distributes the load to the webs of the shoe.

During the erection of the arch, up until the time it is swung, the reaction on the pin is vertical and it is necessary therefore to provide temporary supports for the lower forging and the shoe. For this purpose a temporary extension was built on the lower side of the shoe projecting forward to



KILL VAN KULL BRIDGE: STATUS OF ERECTION, SOUTH END, AS OF JANUARY 29, 1930



KILL VAN KULL BRIDGE—CLOSE-UP OF HINGE AND PEDESTAL DETAILS.

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support the bottom corner of the lower forging and being itself supported on a grillage resting on the masonry shelf in front of the skewback. In this way the vertical load is carried to the abutment, but, as these supports are all back of the pin, tension connections were provided on the upper side of the shoe both between the shoe and the lower forging and between the shoe and the anchor-frame to resist overturning.

Transverse wind acting on the arch during its erection would set up very great longitudinal forces at the shoes on account of the arch structure being, in a lateral plane, a truss with fixed end. It was found very difficult to make adequate tension connections between the various parts at the shoes and into the abutment to take care of this force on the windward side. The contractor, therefore, proposed to get rid of the fixed end condition, and so eliminate this tension, by not completing the half pin holes in the forgings. Instead of following the curve of the pin the portion of the lower forging in front of the pin and the portion of the upper forging back of the pin were cut horizontally so as to allow the upper forging on the windward side to move forward, the pin acting as a roller. The motion required to eliminate a fixed end condition is only about 1½ in.

In order to prevent the whole span rolling forward, due to a longitudinal wind blowing from the shore, a tie-back was constructed on the center line of the bridge extending from the intersection of the bottom laterals at Panel Point 1 to an anchorage in the abutment. This tie-back, to some extent, restores the fixed end condition for transverse wind, but it is of such length that its elastic stretch will relieve it of any excessive tension from that source. The surfaces between which the pin can roll are not really horizontal, but are inclined slightly upward toward the river so that for the slight longitudinal forces ordinarily occurring the pins will not roll.

The shoes were of so great a size that each was made in two parts, the splice between them being reamed with the parts assembled in the shop and each part being separately erected.

DISCUSSION

CHORD SIZE AND ARRANGEMENT, KILL VAN KULL BRIDGE

By C. W. Hudson,* M. Am. Soc. C. E.

In such structures, according to Professor Hudson, there is no standard form or design. So much is a matter of good judgment that probably each engineer would have his own idea as to the proper truss configuration, panel length, rise of arch, and any minor details.

Noting the disparity in the sizes of the upper and lower chords, he observed that,

* Cons. Engr.; Pres., C. W. Hudson, Inc., New York, N. Y.

"It ordinarily leads to simpler detailing if the chords are about the same size and vary in the same direction. Locating the end pin between the top and bottom chords would undoubtedly have accomplished something in this direction and might have resulted in simpler details although the end detail unquestionably would have been much more complicated by that arrangement."

Regarding erection, Professor Hudson's only misgiving was as to the unduly large shortening due to the long overhang. In one condition the fixed arm of the cantilever is about 16 panels, and therefore more than 650 ft., long. This length, in conjunction with the considerable compressive stresses, might well result in "great shortening in this chord".

LARGE ARCH ERECTION IN AUSTRALIA

By D. B. Steinman,* M. Am. Soc. C. E.

Because of a similarity to the Kill van Kull Bridge in size and magnitude, the Sydney Harbor Bridge, Australia, is of decided interest. As Mr. Steinman explained, the city itself has a population well over 1 000 000, or almost one-fifth of the entire people in the Commonwealth. This bridge joins two important districts of the city and therefore will provide for direct highway transportation as well as electric railway and foot traffic serving large areas.

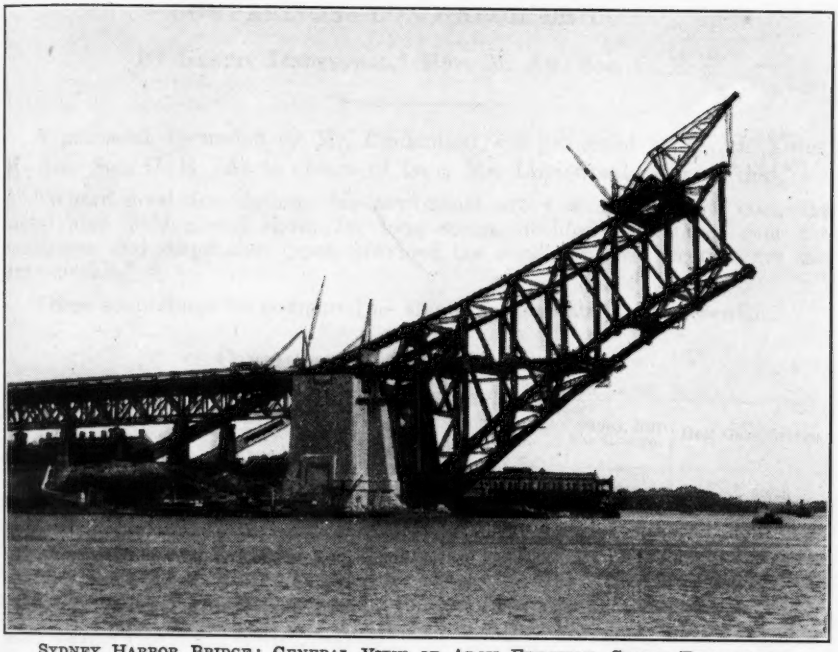
In size the main span is 1 650 ft., center to center of end pins, or slightly less than the Kill van Kull structure. The capacity will be for four tracks of railway, a 57-ft. highway, and two 10-ft. sidewalks. The tracks are placed adjacent to, and on either side of, the main trusses which are 98½ ft. apart, center to center. The roadway is in the middle and the sidewalks on the very outside. In vertical dimensions the arch truss varies from 60 ft. at the center to 188 ft. at the end, the total height being 487 ft. above high water. The panel lengths are longer than in the American bridge, or about 59 ft. each.

Actually, the bridge has been under way for some time, the contract having been awarded in February, 1924. The reason it has not already been completed is to be found in one fact—there have been seventeen strikes. In this respect, according to Mr. Steinman,

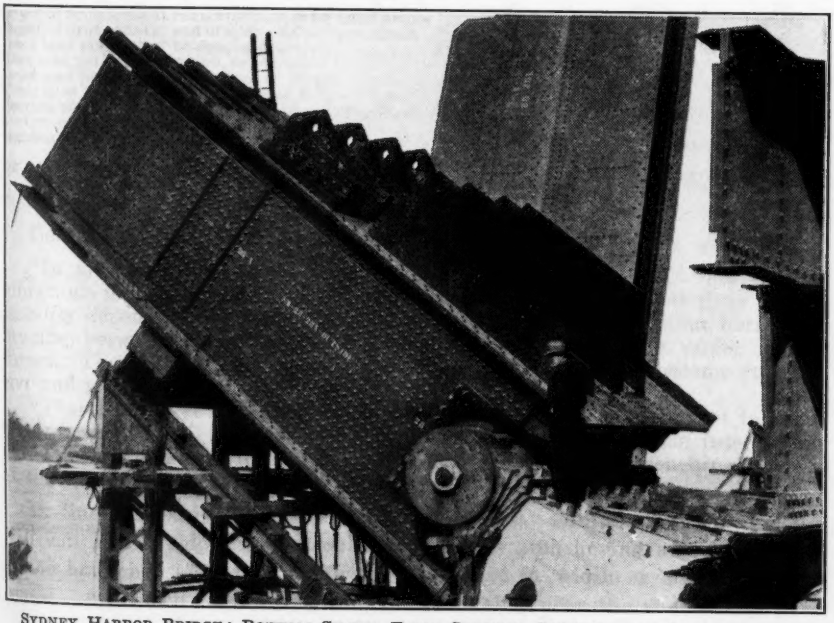
"The contractors in Australia appear to be in a particularly fortunate position—they get time out for strikes. As a result of each strike or demand for higher wages a decision is reached by a Government wage board, and for every increase in wages the contractor is saved harmless; that is a part of the contract."

As an aid in erection the first chord member is divided into six pieces by means of a longitudinal plane of division and three transverse planes. According to calculations when the two cantilevers approach at the middle there will be a gap of from 14 to 47 in., depending upon the temperature. The bridge is proportioned for a total live load of about 12 000 lb. per lin. ft. Possibly this structure will be completed before the Kill van Kull Bridge, stated Mr. Steinman. In this event it will enjoy for a brief period the record of being the longest arch span in the world.

* Cons. Engr. (Robinson & Steinman), New York, N. Y.



SYDNEY HARBOR BRIDGE: GENERAL VIEW OF ARCH ERECTION, SOUTH END, AS OF NOVEMBER, 1929.



SYDNEY HARBOR BRIDGE: BOTTOM CHORD, FIRST SECTION, SHOWING THE LARGE AMOUNT OF FIELD RIVETING REQUIRED.

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COMPARISON—LONG ARCH BRIDGES

By Gustav Lindenthal,* Hon. M. Am. Soc. C. E.

A prepared discussion by Mr. Lindenthal was presented by W. H. Yates, M. Am. Soc. C. E. As to choice of type, Mr. Lindenthal asserted that,

"Where good foundations for abutments are available at low cost, the metal arch bridge will show, for long spans, decided advantages over the cantilever and suspension types, provided the conditions for erection are not unfavorable."

Three such spans he compared as shown in the tabulation herewith.

Comparison—Large Steel Arches.

	Kill van Kull Bridge.	Sydney Harbor Bridge.	Hell Gate Bridge.
Span, center to center of bearings, in feet and inches.	1 652-1	1 650-0	977-6
Rise of arch (bottom chord), in feet	266	350	220
Relation of rise to span	1 / 6.21	1 / 4.71	1 / 4.44
Width between trusses, in feet and inches	74-0	98-6	60-0
Relation of width to rise	1 / 3.59	1 / 3.55	1 / 3.67
Relation of width to span	1 / 22.3	1 / 16.7	1 / 16.3
Width between wind chords, in feet and inches	74-0	156-6*	93-0
Relation of lateral width to span	1 / 22.3	1 / 10.5	1 / 10.5
Width over all (center to center of railings), in feet	90	160*	93
Depth of arch truss at center of span, in feet and inches.	37-6	60-0	* 40-2⅝
Depth of arch truss at end of span, in feet and inches	67-6	187-9	140-0
Dead load per foot of bridge, in pounds	28 000	52 000*	51 000
Live load per foot of bridge, in pounds	7 000	12 000	24 000
Dead load plus live load per foot of bridge, in pounds.	35 000	64 000*	75 000
Total steel in span (including steel in floor), in pounds.	35 700 000	74 000 000*	37 800 000
Section of bottom chord at crown, in square inches	580	1 060	929
Section of bottom chord at hinge, in square inches.	983.5	2 700	1 392
Material in bottom chord	Alloy steel	Silicon steel	High carbon steel

* Figures given are only approximate.

Commenting on the wind and lateral forces, Mr. Lindenthal continued,

"In all three bridges the resultant from wind pressure and lateral floor vibrations is located far above the arch bearings. It follows that their lateral stability depends more than in any other kind of bridge upon stout horizontal bracing between the chords to resist vibration and swaying under lateral forces. The effect of this swaying during high gales is apt to become cumulative and to have the nature of impact.

"Therefore, it would have been worth most any effort or extra cost to avoid the interruption of the wind bracing between the chords at the intersection with the roadway and to avoid the resulting secondary or wrenching stresses at that place."

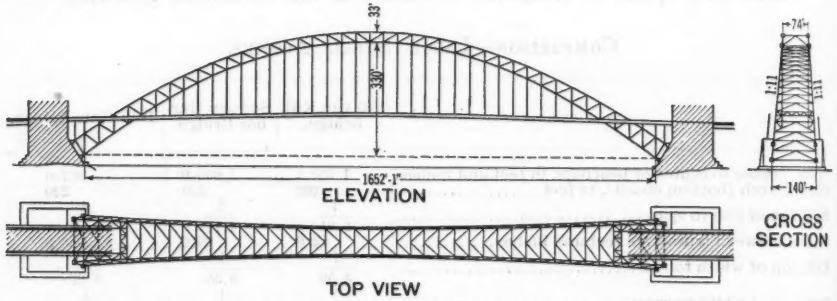
In line with this thought he suggested several solutions suitable for the Kill van Kull Bridge, in particular a hingeless arch having a greater width at the haunches (140 ft.), narrowing to the 74-ft. width as adopted at the center. As shown in the diagram, this widening near the ends would have

* Pres. and Chf. Engr., North River Bridge Co.; Cons. Engr., Jersey City, N. J.

permitted the full 90 ft. of roadway, leaving plenty of room for stout portal bracing without incurring secondary stresses in the arch chords. In addition, he considered,

"Viewed from the ends, this bridge would then have conveyed the expression, architecturally satisfying, of solid, broad-footed stability.

"The hingeless arch with anchored ends is stiffer than the two-hinged or three-hinged arch. The only example in this country of that type is the Eads Bridge at St. Louis, Mo., built in 1874. Although railroad loads over it have increased 100% over those assumed for their dimensioning, the steel arches still do duty. If they had been of the two-hinged or three-hinged type, they would have gone to pieces long ago because of the larger up-and-down deflections.



STUDY FOR KILL VAN KULL BRIDGE: HINGELESS ARCH RIBS WITH FIXED BEARINGS IN INCLINED PLANES.

"The abutments as designed are, of course, amply strong but appear small in bulk."

In common with other discussions, Mr. Lindenthal regretted that it had not been feasible to make the Kill van Kull Arch unique in its beauty.

PLANNING ERECTION

BY CHARLES EVAN FOWLER,* M. AM. SOC. C. E.

Speaking of bridge erection in general, Mr. Fowler asserted that "cantilever, continuous girders, and arches require more study and greater care in execution than any other types of bridge structures." This is evident in the excellent plans for the Kill van Kull erection. Too often the designer gives little thought to erection problems preferring rather to depend on the constructors and by so doing increasing the cost considerably. Fortunately, changes can often be effected to simplify the erection without danger or great additional costs.

Based on numerous experiences illustrating the need of accurate preliminary planning, Mr. Fowler asserted that erection problems were "of much greater interest than many other features of bridge building and second only to the artistic design of the structure". In addition, he believes,

* Cons. Engr., New York, N. Y.

"The use of strain-guage readings as an adjunct to erection and a check upon computed stresses cannot be too highly commended. The reading points can easily be preserved for the entire life of the bridge if desired, and data of untold value to the designer can be procured when the structure is completed, and from time to time in the future as the live load is augmented from the growth of traffic and by the possible addition of rapid transit trains."

GENERAL DISCUSSION

Loads and Efficient Design.—Commenting on the determination of the loading, F. E. Schmitt, M. Am. Soc. C. E., inquired regarding the applicability of the various systems of loading to different parts of the structure. On this general topic he remarked,

"Inasmuch as some members will receive their maximum stress under partial loading, and since the matter of load appears to be a matter of probability, and probability depends upon the length of load, it would appear that the amount of reduction to be made from the amount of load for which a member is to be proportioned, should depend upon the length of loading, giving the maximum stress in that member."

He went on to pay tribute "to the remarkable skill applied to the determination of sections of members in this bridge". As a result chord sections, particularly the lower chord sections, seem to be of very high efficiency. As to the web members, Mr. Schmitt expressed surprise that a latticed design should have been chosen instead of making the cross-section solid.

One question occurred to the Chairman, G. E. Beggs, M. Am. Soc. C. E. In order to take care of erection stresses, the areas of members had to be increased, especially toward one end from the center. He wondered if a certain unbalanced dead loading might not result. The part of the process that interested Jonathan Jones, M. Am. Soc. C. E., especially was the closure of the arch. He inquired regarding the movements effected during this process and also as to the stresses involved.

Author's Closing Remarks.—In answer to the various questions, Mr. Dana offered explanations of many of the points brought up. As to latticing of web members, he believed that the use of a box section would hardly have been economical except possibly for the web members near the end.

The unsymmetrical condition of material in the arch, due to the plan of erection, was not found to be of great importance. Any increase in the stresses was found to be more than balanced by the additional material available there.

The motion pictures shown during the sessions included not only the beginning of erection of the Kill van Kull Bridge, but also most interesting features connected with the new Hudson River Bridge. These latter included both the erection of the footwalks and the spinning of the main cables. The viewing of the pictures provoked much interest and favorable comment. Some of them had never been shown in public before.

SANITARY ENGINEERING DIVISION

JANUARY 16, 1930—2:45 P. M.–5:00 P. M.

The Chairman of this Division, Russell Suter, M. Am. Soc. C. E., opened the meeting by making several announcements involving changes in personnel, programs, etc.

COMMITTEE ON MUNICIPAL CLEANSING PRACTICE

A proposition to inaugurate a concerted, nation-wide study of street cleaning and refuse disposal methods was introduced by G. A. Soper, M. Am. Soc. C. E. As a result of this description of an urgent need, the Division passed the following resolution, which was proposed by Dr. Soper:

"Resolved, That the Sanitary Engineering Division requests the Board of Direction to appoint a Committee on Municipal Cleansing Practice, to include in addition to members of the American Society of Civil Engineers accredited representatives of the following: The American Society of Mechanical Engineers, the American Public Health Association, the American Medical Association, the League of American Municipalities, and the International Association of Street Cleaning Authorities."

RUDOLPH HERING MEDAL

STANDARD OF MERIT REQUIRED FOR THE AWARD

According to the rules governing the award of The Rudolph Hering Medal, it shall be given "to the author of the paper which contains the most valuable contribution to the increase of knowledge in, and to the advancement of, the sanitary branch of the Engineering Profession."

The prize has been awarded once in the three years that it has been offered, and W. R. Copeland, Affiliate, Am. Soc. C. E., offered a few suggestions for encouraging the submission of papers that would more nearly meet the requirements. Specifically, he mentioned the names of several prominent sanitary engineers who were being encouraged to submit papers calculated to set the standard for future papers in this field. Papers on new features, or papers describing results of practical application, were described as especially desirable.

A study of papers for which other prizes had been awarded revealed to S. A. Greeley, M. Am. Soc. C. E., some statistics of interest on this general subject. He reviewed about 150 prize papers that were awarded by the Society in the past 50 or 60 years. According to Mr. Greeley they could be classified roughly into four groups: (*a*) Description of Engineering Works; (*b*) Presentation of Engineering Data; (*c*) Experiment and Research; and (*d*) Papers Relating to Ideas.

During the short time that the Hering Medal has been available, it has been awarded somewhat less frequently than the other six Society prizes. Of the 150 papers for which prizes have been awarded, 28 could be classified as

Sanitary Engineering papers. Of this number, according to Mr. Greeley, 12 were definitely in Class (*a*), 3 in Class (*b*), 9 in Class (*c*), and 4 in Class (*d*).

The average length of the 150 papers was 46 pages, with a minimum of 9 and a maximum of 196 pages. Mr. Greeley outlined five criteria upon which the Rudolph Hering papers might be judged: (1) Length; (2) quantity of work required; (3) literary excellence; (4) usefulness; (5) subject-matter; or type of paper.

In conclusion, Mr. Greeley stated that,

"It seemed to me it might enliven the situation if the papers were judged as they were delivered; take the papers each year as they were read before the Division and use those as the group from which a selection would be made. * * * The Committee report should be a written report giving its comments for record and reference each year so that gradually we could build up a basis for stimulating the contribution of papers and facilitating the judgment."

FILTERING MATERIALS FOR WATER AND SEWAGE WORKS

ABSTRACT OF REPORT OF THE COMMITTEE OF THE SANITARY ENGINEERING DIVISION*

During the year 1929 this Committee continued to study and develop the sodium sulfate soundness test. The subject-matter was presented separately in the form of three Appendices on the following subjects:

I.—An Analysis of the Results of a Co-operative Study of the Sodium Sulfate Soundness Test by Thirteen Materials Testing Laboratories on Selected Samples of Limestone and Slag.

II.—Excerpts of individual Reports with Laboratory Results on the Sodium Sulfate Soundness Test by Thirteen Co-operating Materials Testing Laboratories on Selected Samples of Limestone and Slag.

III.—Results of Fifty Cycles of the Sodium Sulfate Soundness Test.

The question of the scope of the work of the Committee was referred to the Executive Committee of the Division with the result that the following objective was adopted for the future:

1.—The ultimate goal of the investigations should be a final report which after proper consideration and modification might become the basis of a "Manual of Practice" on the subject of filter materials for water and sewage works.

2.—The investigations should include complete consideration of the subject of filter materials for both water and sewage works, with as close a co-operation as possible with other agencies, such as the American Water Works Association.

3.—The results of the various studies should be made available as promptly as possible, presumably by means of progress reports.

4.—A semi-final report should be planned for completion by the end of 1930, covering the subject of methods of testing and selecting of filter materials for sewage trickling filters.

* The report in full will be published in a subsequent issue of *Proceedings*.

The Committee held two regular meetings during 1929 at each of which every member was present. The first meeting was held February 1 and 2, at Kansas City, Mo. The progress report states that this was a joint conference with "the State Boards of Health of Kansas and Missouri with reference to tentative experimental station projects being planned for certain of the State Universities."

The second meeting was held at Cleveland, Ohio, on October 28 and 29, "in connection with which an inspection was made of the trickling filters at the Southerly Cleveland, Akron, Canton, and Alliance sewage treatment plants."

The members of this Committee are as follows: William E. Stanley, *Chairman,* James W. Armstrong, W. H. Dittoe, George B. Gascoigne, and N. T. Veatch, Jr.

GENERAL DISCUSSION

In discussing the best size and depth of filter beds, J. W. Armstrong, M. Am. Soc. C. E., stated that this was the phase of the subject upon which the Committee had concentrated. Quoting directly,

"It [the Committee] felt that it would be useless to try to draw general conclusions from experiments run in one city regardless of the care with which they are conducted.

"Some cities were selected which had to deal with waters typical in various parts of the country. The results of the tests that have been made were plotted and while the Committee does not feel it can draw any definite conclusions, there was a marked similarity in the curves for different sizes of filter sand; that is to say, that in waters of high organic content, the curves were quite similar.

"Indications are that the sizes ordinarily specified for filter sand are too fine for the best operating results. For instance, filters with a top size of sand, 0.04 to 0.045 mm., gave much shorter filter runs and no better effluent than filters containing sand with a top size from 0.5 to 0.62 mm.

* * * * * * *

"As to length of filter runs, there seems to be no great variation between those of the small filters and those of the large units. There was no uniformity of filter runs. They varied greatly, but no more so than did the large filters."

C. E. Keefer, M. Am. Soc. C. E., suggested that the Committee make recommendations as to the size and character of the material that would be best for sludge-drying beds.

In the opinion of W. H. Dittoe, M. Am. Soc C. E.,

"There is almost an unlimited field of investigation that might be undertaken by the Committee and if we undertake all of it, the Committee or its successor in office will be a rather permanent affair in this Division. As one member of the Committee I am favorable to buttoning up what can be buttoned up and not undertaking new things unless the Division wants to undertake them. I hoped voluntarily some members of the Division might be inspired to give the Committee the benefit of the desires of the Division in regard to further investigation and work along this line."

The members of the Committee have ignored several lines of possible investigation that might have been studied with profit, said Thorndike Saville, M. Am. Soc. C. E.:

"As I understand it, they have confined themselves to one series of experiments of single type which they have spread around the country in a number of plants and the results of which should be of great value and interest. On the other hand, there are numerous other phases of this subject, particularly that relating to the size of grain and the methods of testing the sand to indicate the best size."

Tests have been made at the University of North Carolina, Professor Saville stated, to determine

"The best method of measuring the sizes of sand grains with regard to their use in water filtration and for other purposes and we, like other investigators, have come to the effective size and uniformity coefficients as commonly defined and find they are not at all satisfactory."

Starting with methods described by Professor R. G. Tyler, of the Massachusetts Institute of Technology, the investigators at the University of North Carolina branched out on other lines, working toward statistical analyses, etc., including the question of permeability coefficients. Continuing, Professor Saville stated,

"Then again we have taken from an actual filter, starting in with a new filter, this material and we have analyzed the sands the first top 6 in. for the first 600 hours of washing. We took coils of that and analyzed the first quarter inch, half inch, inch, the second, third, fourth, fifth, and sixth inches of that top 6-in. layer, and you would be astonished at the changes which have taken place in distribution of sizes in that 6-in. coil, not only after the first few washings, but with progressive washings.

"After the first 600 hours of washings, the top of the filter has not come by any means to a condition of stability and the effective size is only now approaching a straight line. The effective size at the present time of the top layer is just about getting to the effective size of the entire sand when it was purchased under specification."

This was offered by Professor Saville as an illustration of the numerous lines of investigation open to the Committee. In passing, he advised against devising a manual on water purification or sewage treatment, saying,

"It is all very well to set up specifications. That is a fine thing to do for filtering materials, etc., but as far as a code of practice is concerned, we have not developed anywhere near the point where we should be prepared to say what is best and what is not."

FRICTION OF SLUDGE IN PIPES

FINAL REPORT OF THE COMMITTEE OF THE SANITARY ENGINEERING DIVISION

To the Chairman and Members of the
Sanitary Engineering Division,
American Society of Civil Engineers:

Gentlemen.—Your Committee on Friction of Sludge in Pipes desires to file this brief statement to close up its official status. In view of the continuance of the Committee during 1929 in an effort to complete certain tests which were undertaken on the friction of sludge in pipes of size other than those outlined in the report* made in January, 1929, the Committee now

* *Proceedings*, Am. Soc. C. E., September, 1929, Papers and Discussions, p. 1773.

feels that it is best to state that, owing to circumstances beyond its control, it has been unable to complete the tests.

The data already published or available indicate that the making of sludge tests is complicated by many factors and that the friction may be affected by the method of testing. Certain tests made with ejectors at the Calumet Sewage Treatment Works of The Sanitary District of Chicago indicate that the friction may be higher when the sludge is pumped but once by ejectors than in the tests in which it was returned and used over and over, the circulation being made with a centrifugal pump. There is a possibility of obtaining further data on a working scale in the immediate future.

In view of the situation, therefore, and the inability of the Committee to present at the present time a statement more conclusive than in the report of last January, the Committee respectfully requests that the report of last January be considered a final report, and that the Committee be discharged.

Committee on Friction of Sludge in Pipes,
(Signed) LANGDON PEARSE, *Chairman.*
GLENN D. HOLMES,
January 3, 1930. C. E. KEEFER.

This report was accepted as final by a vote of the Division, and the Committee was discharged.

NEW JERSEY SEWAGE DISPOSAL EXPERIMENTS

PROGRESS REPORT OF THE COMMITTEE OF THE SANITARY ENGINEERING DIVISION

The following report contains a brief summary of the work carried out under the direction of Dr. Willem Rudolfs, Chief of the Department of Sewage Disposal of the New Jersey Agricultural Experiment Station.

The Station has studied a great many problems and carried out experiments and made a great number of biological, chemical, and physical analyses of materials used in research at the laboratory in New Brunswick, N. J., and at plants erected and operating on a large scale at various places outside the Agricultural Experiment Station.

DIGESTION OF SEWAGE SLUDGE AT HIGH TEMPERATURES

Sewage from Cities of Plainfield, Highland Park, and Trenton, N. J.—In a previous report* the fact has been noted that temperature plays an important part in the digestion of sewage sludge. Data have been submitted to prove that, if the sludge is raised from winter temperature to that of summer, the period of digestion can be reduced from four months to two months or less.

Tests carried out during 1929 show that another optimum temperature for digestion exists, ranging from 120 to 140° Fahr. Moreover, under properly

* *Proceedings*, Am. Soc. C. E., March, 1929, Papers and Discussions, p. 601.

controlled conditions, digestion will continue at temperatures as high as 170° Fahr. The relation of period of digestion to temperature is shown in Table 1.

TABLE 1.—Relation of Temperature to Digestion of Sludge.

Temperature, in degrees Fahrenheit.	Number of days required for digestion when ready to draw.
55	120
68	42
82	30
120 to 140	12
170	11

The figures in Table 1 show that, if the temperature is raised by heating from 55 to 82° Fahr., the period of digestion will be reduced to one-third the time required to digest sludge, and that, if the temperature is raised to 120° Fahr., the period of digestion will again be cut down another one-third. The figures, however, indicate that the further decrease in time of digestion, secured by raising the temperature to 170° Fahr., does not reduce the time enough to justify spending the money required to maintain the high temperature.

Enough Combustible Gas Is Generated to Maintain the Heat Required.—Samples of the gas given off during the process of digestion were collected and analyzed. They were found to consist of from 68 to 72% of marsh gas, 16 to 24% of carbon dioxide, very little hydrogen sulfide, nitrogen, etc. If, therefore, the gases set free are conducted under a boiler connected by pipes with coils fastened to the inside walls of the digestion chamber, the burning gases can be made to heat and circulate water through the coils in sufficient quantity to hold the heat in the sludge to 160° Fahr., or more. It is important to note, moreover, that very little H_2S or other foul-smelling gases are given off at these high degrees.

Experiments in other lines of work, for instance, in pasteurizing milk, have shown that most of the common forms of sewage bacteria are destroyed when liquids are heated to approximately 140° Fahr. On the other hand, special forms of bacteria, which are termed thermophylic, grow readily at such temperatures and, in fact, their growth seems to be accelerated. This is the underlying reason why the sludge digests so much faster above 120° Fahr. than it does below 82° Fahr.

Sludge Digested at 120° Fahr. to 160° Fahr. Is More Concentrated.—Measurements made of the volume occupied and percentage of moisture contained show that sludges digested at 120° Fahr. are much more dense, contain less colloidal organic matter, and give up their water more readily than sludges digested at 82° Fahr., or lower. Measurements of the gas given off show also that the volume is greater, comparatively speaking, at the higher heats.

Enzymes

Research has shown that bacteria do not absorb the organic matter in sludge directly, but give off compounds, known as enzymes, which seem to dissolve

the sludge and put it into a form such that the living organisms can feed upon it. "Ripe sludge" contains these enzymes and, therefore, should be added to green sludge as it enters the digestion chamber. Tests have shown, however, that a volume equal to the quantity of green sludge is necessary. Such great quantities of ripe sludge take up considerable space and make the construction of the digestion tanks expensive. It seemed to be worth while, therefore, to isolate the various kinds of enzymes from the ripe sludge, cultivate them artificially, and add "concentrated" doses of them to the green sludge instead of adding ripe sludge. Thus far, however, the experiments have not been very satisfactory. As a matter of fact, each enzyme has certain requirements that must be provided to get maximum efficiency, and the environment suitable for one does not often fit in with the next. Therefore, the tests carried out to date suggest that the sludge would have to be made to pass through a series of compartments so arranged that each enzyme, or at least a group, could be provided with the particular factors that it needs. At present, therefore, it seems that the procedures involved in adding pure cultures of enzymes to sludge are too complicated to be used on a plant-size scale.

Beneficial Action of "Ripe Sludge" Depends upon Age

Sludge that is to be used as seed should have been retained in the tanks for a period such that the processes of "decomposition of the organic matter" will have been carried just far enough to break down most of the more readily digested compounds; but the sludge must not be too old. Experience has shown that after digesting for six months the sludge loses efficiency as a seed.

Concentration of More Than 15% of Solids Prevents Digestion

In order to facilitate digestion the sludge must contain enough water to permit of mixing the "seed" through the mass. Tests have shown that good results are obtained when the sludge contains about 15% of solids and 85% of water. If the solids are allowed to build up more than this the mass becomes so thick that the digesting agents will remain in local areas, and the process of digestion will be delayed.

Analyses show that fresh sludge contains various compounds among which soaps, fats, and crude proteins are most abundant. Next in order come compounds soluble in water and alcohol, hemicellulose, cellulose, lignin, etc. Of these, the fats and soaps and cellulose digest more readily than the other compounds. By the fermentation of these compounds carbonic acid and other organic acids are set free. Observers have noted at times that "foaming" and the development of great numbers of certain kinds of bacteria and protozoa accompany these conditions.

Effect of Organic Acids upon Number of Bacteria and Protozoa Noted

Tests have been made at the Station by adding measured volumes of certain organic acids to the sludge. The results proved that when small amounts of these acids are added the numbers of protozoa and bacteria increase. Such growths do not occur in an alkaline sludge. These tests suggest that the

presence of such forms indicate conditions which will result in foaming, and that some corrective agents, such as quick lime, should be added to counteract the acid. The best form of lime for this purpose is the so-called "high calcium" slaked lime sold on the market in bags as a dry powder. It is particularly desirable to add the lime when tanks are being put into service for the first time and if the weather is cold. A few sacks added at the start and continued from time to time over a period of a few months will serve to get the proper conditions underway for producing ripe sludge. After these have become well established the lime dose can be reduced and eventually discontinued. While being added the lime should be distributed over the surface of the digesting sludge and should not be thrown down in a single spot. When ripe sludge is run out on to sand beds for dewatering, enough area must be provided to allow the water to escape readily. In cold and wet weather the process may be delayed by climatic conditions. To prevent this, many persons advocate covering the sludge-drying beds with a glass roof like a greenhouse, and, in some cases, heating coils have been installed in these "covered" sludge beds to prevent freezing and increase evaporation.

Drainage is More Important Than Evaporation in Dewatering Sludge

Tests have shown that the temperature of sludge must be raised to, and maintained at, 150° Fahr. in order that evaporation shall become as important a factor in dewatering sludge as drainage.

These results indicate that under ordinary conditions drainage is a far more important factor than evaporation in dewatering sludge, and account for the fact that many observers have been disappointed in finding that "covering sludge beds by glass" does not justify engineers in cutting down the area of the drying beds to one-half the usual size. Perhaps it justifies reducing them in area by 25%, but that is all. Moreover, the drying under glass will be very much improved by providing ample ventilation. One of the important factors in this regard has to do with providing a sufficient volume of dry air, kept in circulation over the surface of the sludge to carry off the moisture which rises from the bed.

As a result of experience in the East, operators of sewage plants have come to consider that sludge has not become digested until it assumes a blackish color, but recent tests disprove this theory. At the Testing Station and at many places in the West well-digested sludges are produced which have a gray color and never turn black. Presumably, therefore, the question of color produced is related to the composition of the sewage and sludge. Sludges which contain unusually large quantities of iron, and are digested in such a manner that considerable quantities of H_2S are formed, will have a black color due to the formation of sulfide of iron.

Tests with Industrial Wastes

A part of the work of the Station has been devoted to the effect which certain industrial wastes produce upon sludge digestion. Milk wastes were found to retard digestion when added to sludge in the proportion of 1:3 of sludge. Larger amounts of dairy wastes prevented digestion.

One of the large paint factories discharges a waste containing a large proportion of iron oxide into the sewer. This was found to retard digestion when added to sewage in the proportion of 1 part waste to 5 parts of sewage.

It is interesting to note, in this connection, data obtained in the digestion of sludges taken from the sewage disposal plant at Plainfield and at Trenton (Table 2). The former contains "domestic sewage" sludge and the latter domestic sewage, together with a large proportion of "iron pickle" liquors.

TABLE 2.—ANALYSES OF SLUDGES WITH AND WITHOUT IRON PICKLE LIQUOR. FRESHLY PRECIPITATED SLUDGE FROM SEDIMENTATION TANKS.

	Plainfield domestic sewage sludge, percentage.	Trenton domestic sewage sludge, plus iron pickle, liquor, percentage.
Iron as FE*	4.20	10.11
Solids	4.98	4.35
Ash*	23.20	35.00
Sulfates*	0.40	5.06
Chlorides*	0.34	0.23
pH	6.20	5.40

* On dry solids basis.

The amounts of gas set free during digestion were collected and measured, and the records show that "although digestion was slower" with the Plainfield material, the total gas production during the first twenty days was almost the same in both cases. The total gas production per gramme of volatile matter was in this case again greater for the Plainfield "domestic sewage" solids.

Ferrous sulfate, or so-called "copperas", was added to freshly precipitated solids collected at Plainfield and seeded with ripe sludge. The iron sulfate was added in the proportion of "26 grammes per liter of fresh solids". Analyses of the sludge with iron and without iron were made after incubation for thirty-five days, at which time the digestion was, for practical purposes, completed. These analyses show that the reduction of volatile matter was a little less in the sludge dosed with iron and that the amount of gas produced was a little less, but that the "peak of gasification" was reached in the sludge plus iron a little before it was reached in the sludge without copperas.

For years iron salts have been added to sewage as an aid to clarification in settling basins. Tests made at the Station, using ferric chloride ($FeCl_3$), show that the iron removed more of the finely divided particles or suspended matter than plain sedimentation, and cut down the bio-chemical oxygen demand. "It seems possible that with 5 parts per million $FeCl_3$, the sedimentation time might be cut in half or perhaps to only one-third of that for untreated sewage". Tests made for bio-chemical oxygen demand showed a removal of 56% with the $FeCl_3$ added against 44% without. Ferric chloride has been added to aid in dewatering sludge both before filtration on vacuum filters and on sand drying beds. In tests carried out at the Station it has been shown that by adding 0.5 lb. of $FeCl_3$ per cu. yd. of sludge the same percentage of "water removed" can be obtained in 4 min. as is obtained in 14 min.

when nothing is added. The time is reduced to 1¼ min. with 2 lb. of $FeCl_3$ per cu. yd.

Ferric chloride was added to sludge before running it on to drying beds. Tests made upon samples of treated and untreated sludge show that the moisture in the treated sludge decreased to 82.2% in the same time that it dropped to 85.5% in the untreated sludge. Moreover, it was found that poorly digested sludge will dry much more quickly when ferric chloride is added. For many years ferric chloride was an expensive compound made only in small quantities as a mordant, and for medicinal purposes. It is corrosive, deliquescent, and difficult to handle, as it has a tendency to crystallize from solution when the concentration becomes more than 40 per cent. Now, however, that a good market has been found for its use as a sewage sludge precipitate, two firms are making it on a commercial scale. It is being shipped in tank cars at about 40% concentration, at a cost of about $0.03 per lb.

Chlorination of Sewage Sludge

When sewage sludge undergoes digestion it tends to give off foul-smelling gases and the liquor flowing away contains great numbers of bacteria. Therefore, liquid chlorine is often added to the raw sewage before it is run through the settling basins, for the reason that when Cl_2 is added to the raw sewage in sufficient quantity to ensure that a small amount of residual chlorine remains in the sewage at the outlet, there is less danger that foul odors will escape, and a large number of bacteria will be destroyed. Tests have also shown that the bio-chemical oxygen demand of the sewage effluent will be permanently reduced. This may last for several hours and perhaps permanently. The chlorine seems to enter into a definite chemical union with part of the organic matter so that the bio-chemical oxygen demand may be reduced about 25 per cent. Tests also show that chlorine added to the sewage under these conditions will not retard digestion of the solids or interfere with gas production. The chlorine also has a tendency to combine with H_2S and other easily oxidized "foul-smelling compounds" with the net result that these are removed.

Liquid chlorine added to raw sewage as it enters a settling basin, however, will not sterilize the effluent when the amount of Cl_2 applied is only sufficient to provide a small residual in the tank effluent. Therefore, if the liquor is to be discharged into waters which are to be used for drinking, bathing, or culture of shellfish, it will be desirable to add more chlorine to the effluent as it leaves the tanks.

Composition of Materials for Sprinkling Filters

Comparative tests are now in progress under the auspices of the Station in which four kinds of media are being studied as "filter media". These consist of trap-rock, gravel, slag, and limestone. The results and conclusions are not yet ready for release, but after another year of tests the Station expects to have valuable data for publication regarding the relative values of these various classes of filter materials.

Future Work at the Station

An intensive and exhaustive study of the fundamental biological, chemical, and physical properties of activated sludge has been started, for the purpose of determining the laws which really control the formation and regulate the efficiency of its operation.

Many tests have been made using various types of apparatus for testing the relative advantages and efficiency of the "dilution" as compared with the "direct oxygen" method of determining the bio-chemical oxygen demand of organic matter in sewage, etc. The records obtained to date indicate that for field work, where a simple, but only approximately accurate, method is required, the dilution method is satisfactory. On the other hand, wherever the determination must be exact, the "direct oxygen" method should be used. This investigation is still under way.

A question has arisen in regard to the space which should be provided for storage of sludge in settling basins, and tests are now in progress to determine the density and volume of suspended solids measured against time of sedimentation and depth of liquor. This will be done by making carefully controlled measurements of the amounts of suspended matter contained by liquor in settling tanks at various depths and after various periods of sedimentation. The density should increase and the volume decrease as the period of settling goes on. With a knowledge of these facts engineers will have a scientific basis upon which to compute the capacities of the tanks. Studies based upon the addition of fresh sludge to the extent of 5% by volume of the tank daily will indicate, therefore, what this volume should be after 10, 20, 30 days, etc.

The studies relating to the action of enzymes, being continued to determine their optimum living conditions, throw light upon the question of methods of isolation and design of tank best suited to provide the means of making a practical use of pure cultures of enzymes as against the present method of adding ripe sludge.

Solids removed by running sewage through screens present quite a problem for disposal. They digest better if broken up into fine particles, but many questions remain to be answered as to the kind of equipment to use for shredding the screenings, method of seeding, digesting, and drying.

There is a wide and useful field for the application of liquid chlorine in sewage disposal. Tests are now in progress to determine the basic factors relating to the effect of the chlorine as an agent in stabilizing sludge, control of odors, and allied subjects.

The undersigned wish to acknowledge their appreciation of the kindness, courtesy, and assistance that Dr. Rudolfs has given them in carrying out the work of this Committee, and in supplying data for this report.

George T. Hammond, *Chairman,*
William R. Copeland,
Committee.

December 7, 1929.

WATER-WORKS

REPORT OF THE COMMITTEE OF THE SANITARY ENGINEERING DIVISION

The Committee on Water-Works has been in touch with the activities of the American Water Works Association in bringing out its Manual on Water-Works Practice and in recently organizing committees to bring the information in the Manual to date with a view to publishing in the future a new edition.

In this work an attempt was made to cover the field of sanitary engineering as applied to water-works, and while this has been done in a more or less general way, it has required the co-operation and contribution from members of the Society who are interested in water-works.

Any attempt on the part of this Committee to present papers and discussions on engineering applied to water-works before the Sanitary Engineering Division would have resulted in duplication of effort and expense for publication. The Committee therefore has remained inactive since its organization, but is ready and anxious to take up and present to the Division engineering phases of water-works which are not adequately considered and published elsewhere.

The Chairman is also Chairman of the Committee on Water-Works Practice of the American Water Works Association. The latter Committee is now organizing sub-committees to bring the information published in the Manual on Water Works Practice to date and to present in more detail certain essential phases on water-works which appear to have been inadequately treated in the Manual as first published.

Ultimately the work of the committees of the American Water Works Association will provide the material required for a new edition of the Manual. Obviously, the attempt will be made to cover the entire field of sanitary engineering as applied to water-works, and unless part of this information may be presented to better advantage in meetings of the Sanitary Engineering Division of the Society than at meetings of the American Water Works Association, it will cause duplication of effort and expense for publication to discuss water-works engineering in the meetings of the Division.

This Committee, therefore, needs advice and suggestions from the members of the Division as to how it may best serve the Division and the Society. All the members of this Committee are workers in the American Water Works Association and will be glad to divide their activities between this Association and the Sanitary Engineering Division of the Society if a way can be found to do this without duplicating effort and publication expense.

The Committee on Water-Works has considered the advisability of attempting to prepare a Manual or a "Separate" on engineering as applied to water-works which might be of value to engineers, by presenting data and present-day practice in a form and in detail which would not be suitable for the Manual of Water Works Practice. This suggestion has not received

whole-hearted support, and it is doubtful if the effort and expense would be justified by the amount of additional information presented in this manner over that provided in the publications of the American Water Works Association.

If it is the desire of members of the Division to have engineering problems in water-works design and construction brought before the Division, it is possible that a plan of co-operative development of information on water-works might be worked out between the Division of the Society and the American Water Works Association.

A precedent for such co-operation is found in the publication of Standard Methods of Water Analysis jointly by the American Public Health Association and the American Water Works Association. If similar co-operation could be arranged between the Sanitary Engineering Division of the Society and the American Water Works Association, it would be possible to present many papers on engineering subjects for consideration and discussion at meetings of the Division, which are now presented at general and divisional meetings of the American Water Works Association. In this way, part of the information essential to the editing of a new edition of the Manual on Water Works Practice could be presented, discussed, and published by the Society.

This Committee believes that the limited funds available to the Division can be best utilized for the present in the development of practices in sanitation other than water-works while this subject is being covered so thoroughly in committees and publications of the American Water Works Association. The Committee, therefore, recommends that it be discharged.

Respectfully submitted,

MALCOLM PIRNIE, *Chairman,*
C. A. EMERSON, JR.,
CHARLES GILMAN HYDE,
C. W. SHERMAN,
ABEL WOLMAN,
Committee.

January 16, 1930.

This report was accepted as final by the Executive Committee of the Division, and the Committee was discharged.

After considerable discussion dealing with the importance of retaining matters pertaining to water supply as a part of the work of the Division, a motion was carried expressing the approval of the Division to the appointment of a committee to retain the identity of the Division in its relation to, and its participation in, water supply matters.

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CONSTRUCTION DIVISION

JANUARY 16, 1930—2:35 P. M.–4:00 P. M.

The meeting was opened by W. J. Barney, M. Am. Soc. C. E., who prefaced his introduction of the incoming Division Chairman by a few remarks concerning the activities of the Division during 1929.

DIVISION ACTIVITIES

By W. J. Barney,* M. Am. Soc. C. E.

In lieu of a report by the Executive Committee of the Division, Mr. Barney called attention to the statement published in Part 2 of the January and February, 1930, issues of *Proceedings*. In brief,

"Six committees are collecting and compiling data relative to Construction Plant and Methods in the various lines of construction. It is anticipated that these reports will be sufficiently complete during the coming year to justify their issuance in the form of a manual on this highly important subject of Construction Plant and Methods."

The formation of the Construction Division four years ago "marks an event of the deepest significance", declared Mr. Barney, because it denotes official recognition of the fact that to-day,

"The Engineer has become the Contractor, and the Contractor has become the Engineer, with a constantly increasing mutual understanding and respect to the greater benefit and efficiency of the engineering construction industry."

Mr. Barney then introduced J. P. H. Perry, M. Am. Soc. C. E., as the incoming Chairman of the Division.

HYDRAULIC PLANT AND ITS APPLICATION TO UNDERPINNING STRUCTURES ALONG THE NASSAU STREET SUBWAY

By Herbert M. Hale,† M. Am. Soc. C. E.

The construction of the Nassau Street Subway in New York was marked by two unusual features. It was a narrow job in a narrow street and, according to Mr. Hale,

* Pres., Barney-Ahlers Constr. Corporation, New York, N. Y.
† Managing Engr., Marcus Contracting Co., New York, N. Y.

"Probably it is the only subway job in New York City where some form of power shovel was not used. A large part of our plant in that respect was human, consisting of as many strong-backed and strong-armed men as we could gather to wield the old-fashioned shovel and cast the excavation by means of belt conveyors into trucks.

The other feature was in the use of special hydraulic plant in the underpinning of buildings. A summary description of the work may be listed under nine items as follows:

"1.—The job is a little short of a half mile in length from beneath the Municipal Building to the south side of Liberty Street.

"2.—Nassau Street is only 35 ft. wide between buildings.

"3.—The subway structure occupies all the street width.

"4.—The material throughout is sand ranging from medium coarse and fine to a fine quicksand. The quicksand condition prevails generally from Ann Street to Liberty Street. In other words, the south half of the job is quicksand.

"5.—Fifty-two buildings, twenty-seven elevated columns, and two blocks in length of the East Side Subway had to be maintained or directly underpinned.

"6.—Many other structures under heavy loads required additional underpinning.

"7.—The buildings ranged in height from four to twenty stories above the street with some of them having two stories of basement below the curb.

"8.—Excavation required the removal of all material to the building lines and to as great a depth as 20 ft. below existing building foundations in quicksand below water level.

"9.—The pre-test system of underpinning developed on the old William Street Subway and patented by Spencer, White and Prentis, Incorporated, was used. The general underpinning operations required more than 30 000 ft. of 14-in. and 16-inch steel piles of an average length of 30 ft. All piles were put down to a depth of from 4 to 6 ft. below sub-grade and pre-tested in the existing material as no rock in this section is nearer than 50 ft. below sub-surface."

The plant consisted of a main air compressor unit with distributed air pressure along the line of work, an accumulator for automatic hydraulic pressure, copper hydraulic pipe for the distribution of hydraulic pressure, jack hangers, jacks and gauges, Marlo mud-hog pumps, augers, and small orange-peel buckets.

With the assistance of numerous slides, Mr. Hale described the ground layout of the job. It was divided into two contracts involving the construction of the two ½-mile sections between the end near the Brooklyn Bridge Approach and South Ferry. The excavation work involved no rock; there is fairly good sand and some quicksand.

Interesting in this connection, as applied to underpinning, is Mr. Hale's statement that the old, smaller buildings are of more concern than the taller, more substantial modern types.

The remainder of the description applied directly to the slides as each one was thrown on the screen. In this manner, a graphic portrayal of plant and method was presented. The methods of operating the jacks to drive pile sections was shown in detail.

PLANT USED ON THE FULTON STREET–EAST RIVER SUBWAY TUNNEL

By Miles I. Killmer,* M. Am. Soc. C. E.

The work described in this paper is known as Route 101, Section 1, of the New York City Subway. Its location and the scope of the work were outlined by Mr. Killmer, as follows:

"The contract begins on Church Street about 100 ft. south of Park Place. Local and express tracks run south on Church Street to Fulton, where the local tracks terminate at a station next to the Hudson Terminal Building. The two express tracks turn east, pass under the southbound B. M. T. tube in a short section of concrete tunnel, and continue east in separate cast-iron tubes to the end of the contract in Brooklyn, at Jay and Nassau Streets. Following the cast-iron tubes from west to east, one passes under the northbound B. M. T. tube, St. Paul's Churchyard, Fulton Street, to East River, Cranberry Street, High Street, and under private property to the end of the job.

"The tubes were constructed by the shield method under compressed air. The working shafts are at Fulton and Front Streets, Manhattan, and on Furman Street, Brooklyn. Shields started east and west from each of these shafts in each tunnel, making eight shields in all. From January, 1929, until May of the same year, all eight of the shields were under way together. In Brooklyn, the ground passed through by the shields was mostly sand, gravel, and boulders. In Manhattan, the ground was a fine sand with clay admixture and was very favorable for tunneling. The Manhattan shields passed under the I. R. T. in William Street, the I. R. T. in Broadway and the easterly B. M. T. tube near Church Street, and the Brooklyn shields passed under the approach to the Brooklyn Bridge in Brooklyn. Along the line of march through Fulton Street were many tall buildings whose footings were vertically close over the shield and horizontally only 2 or 3 ft. away from the outside of the tunnel. These buildings were not underpinned.

"The air pressure used in the shield-driving and in putting down the mid-river sumps ranged all the way from normal to 48 lb.

"The work included also two stations in Manhattan, to be constructed by cut-and-cover methods and a station in Brooklyn to be constructed by tunneling."

Power Houses

Two power houses were established, one in Manhattan and one in Brooklyn, to supply air. In Manhattan, the current was received through three feeders, 13 200 volts in one and 7 500 volts in each of the other two. This was stepped down to 2 200 volts for the larger motors and 220 volts for the smaller ones. In Brooklyn, current was received from three feeders at 4 300 volts and was used at that voltage for the large motors.

Each feeder, according to Mr. Killmer, entering a power house came from three different sub-stations to insure a supply of power from two sources if one should fail. Describing the equipment, Mr. Killmer stated that in each power house there were four new low-air compressors, 29 by 29 by 21 in., and one used low-air compressor, 28 by 28 by 24 in. The capacity of each

* Gen. Supt., Mason & Hanger Co., New York, N. Y.

was 5 600 cu. ft. The new machines were operated by synchronous motors of 625 h. p. and a full-load speed of 180 rev. per min., and the others by 600-h. p. motors with full load speeds of 164 rev. per min.

For high-pressure air, each power house had three 20 by 12½ by 14-in. compressors, with capacities of 1 300 cu. ft. These were operated by synchronous motors (225 h. p.) using 3-phase, 60-cycle current at 220 volts. The full-load speed was 257 rev. per min.

Commenting on the quality of the air, Mr. Killmer stated that,

"The air for the compressors was taken in above the roof. In Manhattan, the inlets were equipped with filters to remove some of the dust of the city streets. By taking in the cooler air from outside the power house, one not only gets better air but better compression economy.

* * * * * * *

"The high air could be turned into the low-air lines if need be and was, in fact, so used in Brooklyn on several occasions."

As for hydraulic machinery, in each power house there were three 4-plunger, horizontal pumps with plungers of 1¾-in. diameter and 12-in. stroke. They operated at 50 rev. per min. by means of gear-connected motors with 100 h. p. and a full-load speed of 700 rev. per min. The capacity of these pumps was 24 gal. of water per min.

An 8 by 42-in. hydro-pneumatic accumulator was described by Mr. Killmer, in which the load is applied by a cylinder charged with compressed air instead of by the old weight method. This plant was connected with the work as follows, quoting Mr. Killmer:

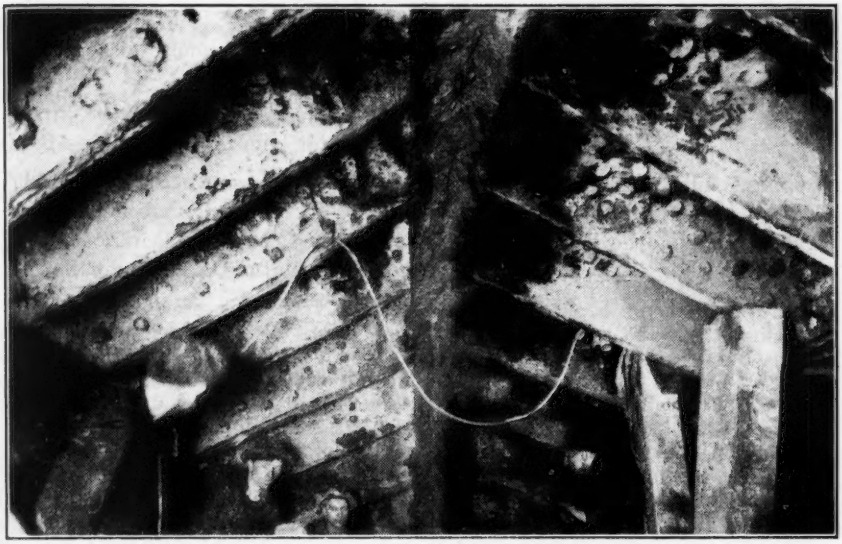
"The power houses were connected to the shafts by the necessary air, water, electric, back-pressure, and telephone lines, laid in trenches below street level. In Manhattan, the power house was only one block from the shaft and two 14-in. lines sufficed to carry the low-pressure air. In Brooklyn, the distance was ½ mile, and two 16-in. lines were used. The contract required two lines to each heading. To secure maximum safety and flexibility, the various air lines are cross-connected.

Shields.—Mr. Killmer stated that there were no unusual features in the design of the eight tunnel shields. In his own words,

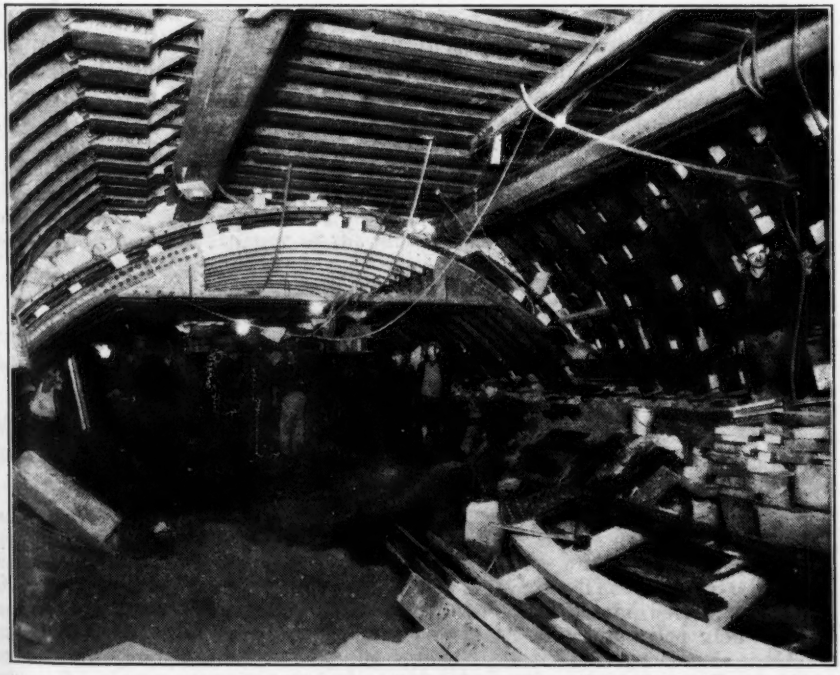
"There were no unusual features in their design. Since the material to be encountered in all the tunnels was sand or gravel and, since there was no possibility of shoving blind at any stage of the job, the shields were entirely open. The shield had one platform across its horizontal diameter. The spaces above and below the platforms were each divided into three pockets by two vertical partitions. The lower middle pocket was made large enough to permit a muck car to pass through to the face, but the conditions of the job never required the use of this facility. The skin plates of the shield consisted of two 1¼-in. plates riveted and welded together.

"Two circular girders or diaphragms formed the stiffening structure. As much as possible of the work of fabrication was done at the shop. A quadrant of the skin and quadrants of the stiffener girders with cutting-edge or hood castings attached were riveted together in the shop."

Describing a piece of equipment used to speed up shield erection, he said that,



THE HOODS OF THE TWO SOUTH RIVER SHIELDS MEETING AT THE CENTER OF THE RIVER.



METHOD OF SUPPORTING THE GROUND BY MEANS OF PRESSED STEEL LINER PLATES, STEEL RINGS, AND BOWSTRINGS AS USED IN EXCAVATING FOR THE BROOKLYN BRIDGE PLAZA STATION.

"An ingenious device was used to speed up shield erection. Rollers were built into the cradle so that the assembled shield could be rotated about its axis. The seams along which the skin-plates were to be welded could thus be brought into the clear for easier access. The insertion of the jacks into their places was made much simpler, for they were all put in at the bottom. The rolling of the shield was done by the derrick pulling on a wire cable wrapped several times around the outside of the shield."

The outside diameter of the shield was 18 ft. 10 in., and the outside diameter of the tunnel was 18 ft. 3 in. The thickness of the skin was 2½ in. and the theoretical clearance between the outside of the iron and the inside of the tail was 1 in. Quoting Mr. Killmer,

"The shields were very heavily constructed and stood up well for the duration of the job. On the Brooklyn side boulders were of very common occurrence; in some cases pieces were broken out of the cast-steel hood segments by hidden boulders. Both land and river shields were equipped with hoods extending 2 ft. 10 in. farther ahead than the cutting-edge; the hoods on the land shields reached to 1 ft. below the springing line on either side while the hoods on the river shields reached only to a point 1 ft. above the springing line. The total length of the shield along the bottom was 15 ft.; 6 ft. 6 in. of this was in the tail, 5 ft. 2 in. was between the rear diaphragm and the front diaphragm and the remainder made up the forward part of the shield consisting of the cutting-edge castings and the steel structure to which they were anchored."

The shields were pushed by eighteen jacks, eight above and ten below the springing line. Exerting 6 000 lb. per sq. in., the total thrust on a shield was 4 000 tons. Despite the usual offset foot designed to apply the pressure to the web of the cast-iron segment, the shield was broken several times by the jacks. To quote Mr. Killmer directly,

"To reduce the number of such breakages, steel shoes were made in the blacksmith shop and fastened on to each jack. These shoes were designed to limit the area over which the thrust was exerted against the segment, and also to overcome the tendency of the moving part of the jack to twist."

Plant in Rear of Shield.—This part of the paper described the working of the traveling platform. Among other things, it "served a bolting platform in re-tightening the back rings and it carried the grout pan and the two gravel pans."

The use of these gravel pans to eject pea gravel outside the cast-iron lining was fully described by Mr. Killmer. The pan, so-called, is a tank with a capacity of 33 cu. ft. of gravel. Quoting from the paper,

"There is an air-tight trap door at the top through which the gravel is loaded. When the tank has been charged, the door is closed by admitting high-pressure air to the tank. Below the bottom nipple is a tee, on one side of which is an 1½-in. hose with valve and on the other side an armored rubber hose leading to the grout hole in the segment. The valve in the air line is opened and immediately thereafter, the valve at the bottom of the tank is opened. The gravel falls into the air jet and is carried along the armored hose and ejected outside the tunnel lining. This process is under way as the shove progresses and the void left by the advancing tail of the shield is filled with the ejected gravel before the ground has a chance to cave

in. The process packs the gravel in tightly and almost cements it together. The material may be ejected dry or the charge in the tank may be inundated with water before shooting.

"On the land headings, both in Manhattan and in Brooklyn, great stress was laid on this operation to insure the instant and complete back-filling of the void made outside the cast-iron lining by the advance of the shield. Had the overlying ground been permitted to fall into this space, disastrous settlement of adjacent buildings would have resulted. In fact, the success of the whole tunneling procedure was linked to the success of this operation."

Of equal importance is the ejection of grout outside the cast-iron lining. This is the second line of defense, according to Mr. Killmer. As for the design of the grout pan used for this purpose, no important changes have been made since the construction of the Pennsylvania Tunnels.

Storage Facilities.—Dock space was available in Manhattan for handling segments, grouting sand, pea gravel, and cement. Enough reserve segments were stored here to supply the job for four days if transportation was cut off from the larger storage space in the yards of the Jersey Central Railroad, in Greenville, N. J. When the work was going at maximum pace, 48 rings per day were erected; that is, about nine carloads.

Shaft Plant.—This was described by Mr. Killmer, as follows:

"The shaft plant on a tunnel job is required to take care of two very different shaft conditions. There is, first, the period when shields are being started from the shaft. The deck is in place in its upper position and the space below is under compressed air. All materials pass in and out through locks above the cassion deck. Matson locks on 3-ft. shafting were used at the gantry level. The manlock was of the usual tee-head shape and was at street level.

* * * * * *

"After all headings have been started and temporarily bulkheaded, the shaft plant undergoes a complete change. Concrete bulkheads with locks are constructed in all the tunnels. Henceforth, the shaft will be in normal air; the compressed air will be beyond the tunnel bulkhead.

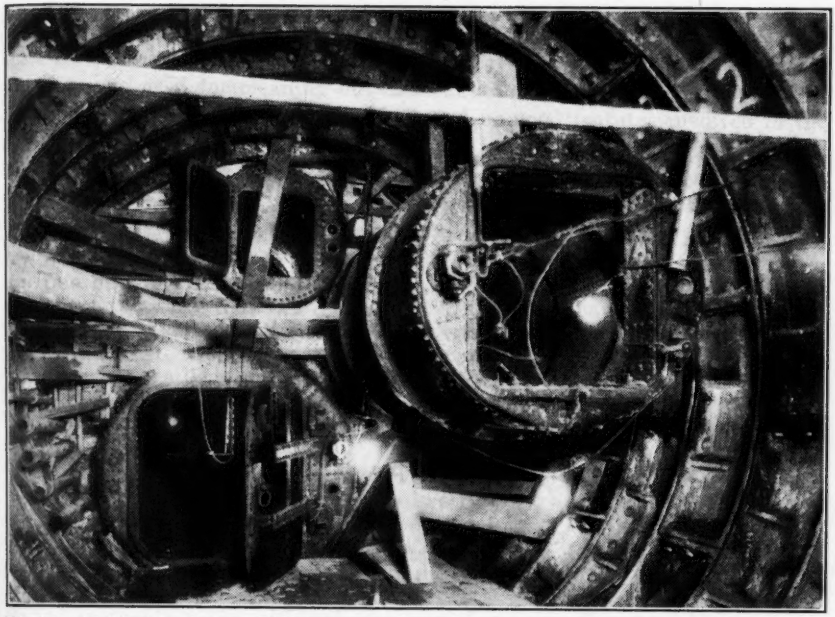
"Steel framework is then built up from the bottom of the shaft to above gantry level. This frame forms the hoistway and supports the cage hoists above the well. On the Fulton Street tunnels, the cage hoists were operated by push buttons. This is the first time that this type of equipment has been used. It worked out very well."

Tunnel Bulkheads.—No unusual features were involved in the tunnel bulkheads. As for dimensions, Mr. Killmer pointed out that,

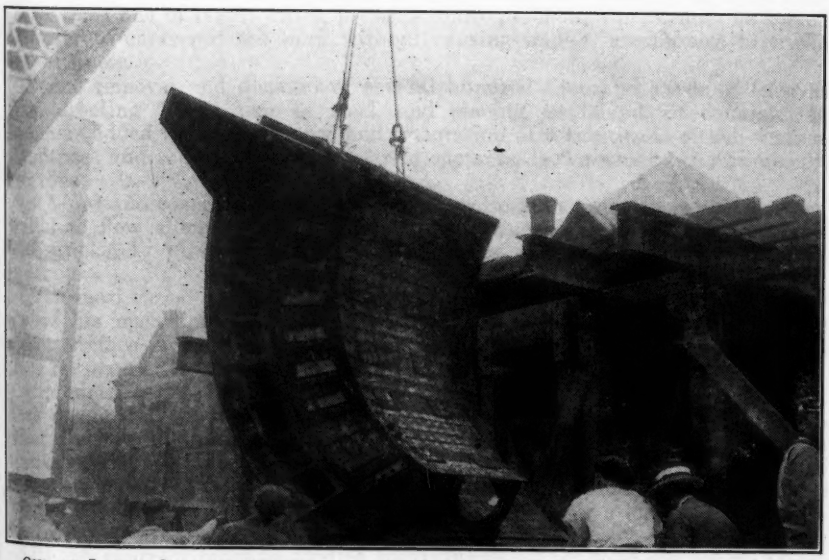
"Because of the large-sized cars used, the muck locks had to be 8 ft. 6 in. in diameter. They were 38 ft. long. The man locks were 6 ft. 6 in. in diameter and 34 ft. long. The emergency lock placed as high as possible in the bulkhead, was 5 ft. 0 in. in diameter and 20 ft. long. The concrete wall of the bulkhead was 6 ft. 6 in. thick in the land headings and 8 ft. thick in the river headings.

"In addition to its locks, each bulkhead contained two 10-in. air lines, two 6-in. blow lines, one 4-in. high air pipe, one 3-in. water line, two 1½-in. hydraulic lines, a back-pressure pipe, and several iron conduits for electric cables and telephone wires.

"After the river shields had advanced about 1 000 ft. from the tunnel bulkhead near the bottom of the shaft, a second bulkhead was built close behind the shield. After this bulkhead had been put in use, the air pressure in the section of tunnel between the two bulkheads was maintained at about 15 lb."



TUNNEL BULKHEAD UNDER CONSTRUCTION, SHOWING MUCK LOCK AT LOWER LEFT, MAN LOCK ON THE RIGHT, AND EMERGENCY LOCK AT TOP OF CONCRETE BULKHEAD.



ONE OF LOWER QUARTER-SECTIONS OF A SHIELD IN SLINGS OF A DERRICK READY TO BE LOWERED; CUTTING-EDGE IS TOWARD THE CAMERA.

Conclusion

The south river shields met in May, 1929. The work of placing the concrete lining was begun toward the end of August and much of the intervening time was required for cleaning out and caulking.

In closing, Mr. Killmer described several unusual features involved in the construction of the station to be constructed under High Street in Brooklyn. This completed the picture as far as plant equipment was concerned. Finally, Mr. Killmer stated that,

"Several new items of plant would be welcome, but have not yet been devised. A number of attempts have been made to develop a bolt-tightening machine but, to date, this problem has not been solved. We did use a small air-driven tightener that ran up the nut, but did not have the power to complete the job. The final tightening was done by two or three men pulling on a 5-ft. hand wrench with ratchet attachment. Belt loaders were used for a time, but the available space is so small that the advantages of the loader were outweighed by its disadvantages."

CONSTRUCTION METHODS AND PLANT ON CUT-AND-COVER SUBWAY WORK

By J. H. C. Gregg,* Assoc. M. Am. Soc. C. E.

This valuable paper, although quite brief, was supplemented by numerous slides. The subject-matter is published substantially in full:

"Subway construction, occurring as it so frequently does in the most congested portions of larger cities, presents many problems which must be solved in order to carry out the work without causing undue interference to traffic and business.

"The removal and disposal of several hundred thousand yards of excavation, erecting 10 000 tons of steel, and placing 40 000 yd. of concrete, to which is added the maintenance and restoration of a multitude of sub-surface structures and the replacement of street surfaces, is the usual size of contract awarded.

"A cut-and-cover method is almost compulsory in order to permit modern traffic to flow along—traffic consisting of a constant stream of automobiles and trucks, to which is added, in some cases, a double-track street-surface railroad.

"In most cases the conditions compel the contractor to carry on the majority of his operations underground. After the top cut is removed and the street surface is replaced by decking, the dirt must come up from below and in such manner as to be moved quickly from the job.

"Modern street decking with its 5-in. or 6-in. planks, supported on steel deck beams and capable of carrying loads which modern trucks haul, is somewhat stronger than the decking of twenty years ago when the horse-drawn trucks of that day were in use. A safe rule to follow is to design a deck of sufficient strength to carry the contractor's own equipment. A modern crane with caterpillars moving from place to place is as heavy a load as one usually has to take care of.

"Each contract must be studied individually. That fond old saying 'Time is the essence of the contract', stares one in the face from the beginning, and

* Chf. Engr., Oakdale Contracting Co., New York, N. Y.

a careful analysis must first be made to insure the completion of the various steps on a set schedule so as to complete the whole within the specified time.

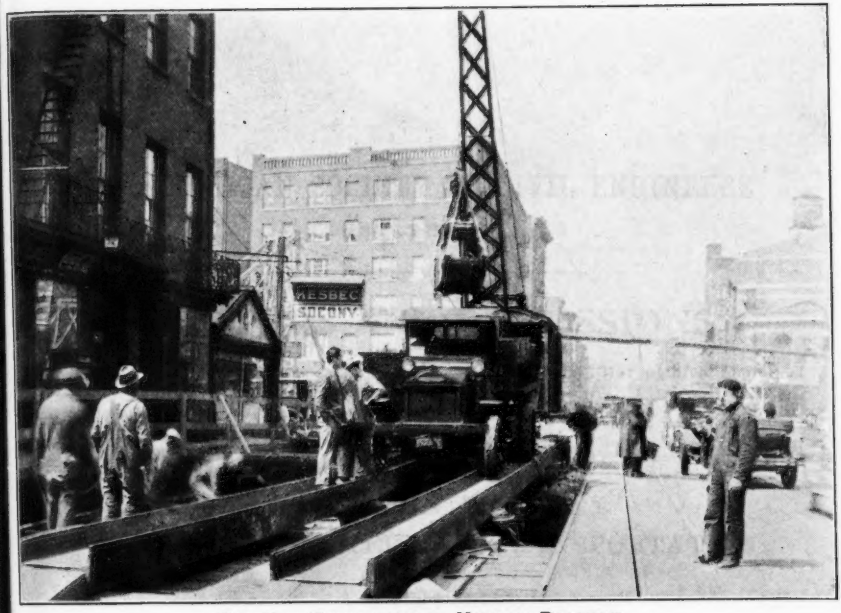
"Local conditions must be studied to see how the various operations can best be carried out with speed and safety, and to aid in the choice of plant with which to best perform the work on hand.

"The application of standard equipment or more often equipment modified to suit local conditions is the usual result. In principle, the methods of handling a subway contract differ but slightly from those used on any large-scale construction job. Power machinery is in common use as labor is neither plentiful enough, nor, in this day, in the mood to endure the strict régime in force a score of years ago. One sees, therefore, steam, air, gas, or electric shovels, gas cranes, all types of pneumatic machinery and tools, in common use in the endeavor to keep the job on schedule requirements.

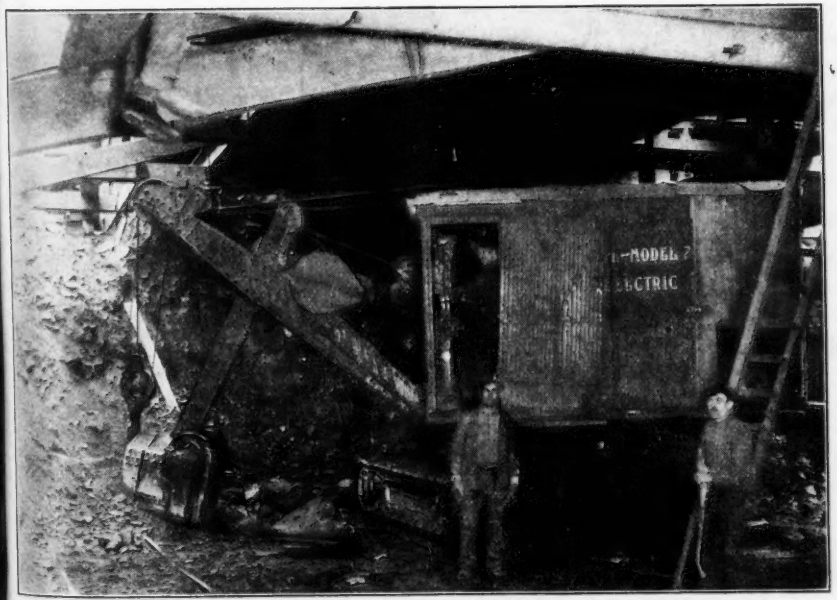
"There are six major steps in each contract—underpinning of buildings, by-passing of gas mains, excavation and decking, steel erection, concrete, then sub-surface and street restoration.

* * * * * *

"Excavation naturally receives the bulk of attention. As excavation goes, so goes the job, and the man who moves his dirt quickly and economically is the man who turns out successful work."



TOP CUT EXCAVATION IN NARROW ROADWAY.



STANDARD SHOVEL WITH SPECIAL BOOM FOR WORK UNDER STREET DECKING.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

RELATION BETWEEN RAIL AND WATERWAY TRANSPORTATION: A SYMPOSIUM*

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* Presented at the Technical Session, Annual Convention, Milwaukee, Wis., July 10, 1929. Written discussion on this Symposium will be closed in August, 1930.

WATERWAY TRANSPORTATION FROM THE VIEWPOINT OF OPERATION

By T. Q. Ashburn, Maj. Gen., U. S. A.*

Synopsis

This paper gives a discussion and comparison of private, contract, and common carriage, as well as common carriage under joint rail and water rates, on three types of inland waterways: Lake type (Great Lakes and connecting channels), per ton-mile cost, 0.64 mill; lock-canal type, closed by ice part of year (New York Barge Canal), per ton-mile cost, 3 mills; and river type, adequate channel open the year round (Mississippi River, St. Louis and South), per ton-mile cost, 1.07 mills.

The expense and difficulty incident to development of, and also the benefits to the general public from, these types of water carriers, increase in the order in which they are mentioned.

The development of private and contract carriage on the waterways creates monopolies which destroy healthy competition. To prevent this, common carriage should be developed and the benefits of this type should be extended to communities off the waterways through the establishment of joint routes and rates in which both water and land carriers participate.

The Inland Waterways Corporation is an agency set up by Congress to develop joint land and water common carriage. Analysis of the Barge Line dollar shows a deficit of 3 mills in 1927 and a net income of nearly 6 cents in the succeeding year. The Corporation has demonstrated that it can operate on freight rates which give a substantial saving under all rail rates and, at the same time, by fair divisions of the revenue afford each participating carrier a living, thus proving that the Nation's policy to render its streams navigable in order to reduce transportation costs is not a mistake.

From Noah's time to this—a lapse of thousands of years—every man who throws himself whole-heartedly into the struggle for inland and coastwise waterways transportation meets the same objections and criticisms that old Noah met; but they have continued determinedly, and time and experience are dumfounding their critics, even as Noah did when his ark, with its precious burden of freight, rose upon the crest of the waters and saved the faithful few of those days, who believed in water transportation.

Expansion of Civilization and Transportation

The expansion of civilization is coincident with the expansion of transportation. Wherever civilization may have first appeared, it spread solely through contact with the outside world; and only as fast as such contact could be made. First, such contact was made by means of the legs of the human being; then through the animals he trained to support him; then through the

* Chairman and Executive, Inland Waterways Corporation, Washington, D. C.

slow-running vehicle, developing into the railroad trains, the automobiles, and the airplanes of to-day. The log that drifted down stream, the sluggish flat-bottom raft propelled by poles, developed into the ocean racers and the marvelous towboats of to-day.

In its ultimate analysis, all communication between individuals, between communities, between States and nations, is some form of transportation. Speech is the transportation of sound through the air; the telephone, the telegraph, the wireless, the heliograph, all depend upon the transportation of sound or signals; and as civilization expanded, its onward course was marked and limited by the development of transportation.

With the growth of civilization began the growth of trade and commerce. As these took the form of water carriage and venturesome voyages, the necessity for agreements between neighboring sea cities became apparent—harbors and lighthouses had to be constructed for the safety of trade, and thus began that slow growth of mutual agreement or mutual accommodation, which is the basis of whatever international law exists.

Necessity Develops Transportation

Transportation brings from one end of the world to the other the products of Nature and of Man, and as the necessity of these products grows, be they raw or manufactured, so must transportation facilities advance.

Civilization brings in its train the demand for necessities, comforts, and luxuries, in the order named. Nature has ordained that the raw material needed in the manufacture and production of necessities, comforts, and luxuries should grow in widely separated portions of the globe. Certain kinds of grain, rice, and sugar cane, grow only in certain localities; various kinds of ores are produced at one place and turned into steel and iron at another place. The silks of China and Japan are as actual necessities to American women as are the farming implements of America, the products of great steel industries, the locomotives, in fact, all American exports, to South America, Europe, Asia, Africa, and Australia.

The laws of economical production demand that great manufacturing centers shall be located where cheap raw material can be obtained, and where the cost of distribution of the manufactured article is cheapest, provided there is no great difference in labor costs. A combination of these two elements, where the raw material is an import, naturally suggests a seaport. If the distribution can also be made from that seaport, so much the better. The sea is a universal highway—the cheapest means of transportation known. The reason for this is self-evident.

Consequently, every inland city, located upon a navigable waterway, dreams of the time when it shall be an inland seaport. If navigable highways are developed as they should be, it will only be a matter of a few years until such cities as the "Twin Cities" of St. Paul and Minneapolis, Minn., Cincinnati, Ohio, Pittsburgh, Pa., St. Louis and Kansas City, Mo., Omaha, Nebr., Montgomery, Ala., Albany, N. Y., Cairo, Ohio, Memphis, Tenn., Birmingham, Ala., Vicksburg, Miss., and many others will be actually, if not geographically, seaports. In a somewhat limited sense the Great Lakes cities are already seaports.

Three Distinct Problems

The navigable inland waterways of the United States, from an operating standpoint, naturally fall into three distinct classes, the Great Lakes, improved rivers, and canals. An examination of the required investment in floating equipment, physical conditions of operating channel, terminals, and overhead, necessary for successful operation upon these various water highways, is profitable regardless of the cost of creating these channels.

Since no charges are made for the utilization of any of these waterway avenues, the practical operator is not concerned with their cost of construction, nor is he inclined to view with alarm any enormous expenditures made, so long as they have been made, and so long as all the avenues are open to him without cost.

He accepts the situation as it is, and leaves to economists, statisticians, and college professors the academic question of whether Congress was right or wrong in spending money for such purposes. He says, in effect,

"The Government may have been right or wrong in spending money to create these channels, but so long as the money has been spent, it has been spent, and academic discussion does not concern me; what does concern me is whether I can profitably operate upon the channels which have been created by the Government by the expenditure of such funds."

Physical Conditions

The amount of money to be expended for the creation of a successful single unit for operation depends largely on physical conditions of operations. The Great Lakes are open for navigation approximately eight months of every year. The New York Barge Canal rarely has more than seven full months of navigation, but for comparative purposes it will be credited with eight. The Upper Mississippi, extending from the "Twin Cities" to St. Louis; the Missouri, from Kansas City to St. Louis; and the Chicago-Illinois River route are ice-bound approximately 3½ months per year. On the other hand, the Lower Mississippi is open the year round for navigation, as is the Warrior River. Ice obstructions on the Ohio are negligible during the entire year.

It is evident, therefore, that successful operation upon the Great Lakes, the New York Barge Canal, the Upper Mississippi, the Illinois-Chicago River route, and the Missouri, requires the accumulation of enough profits in eight months to make a reasonable return upon the investment for a whole year, or that some other use of the equipment must be found during the closed season.

The closing of the Port of St. Louis has no appreciable effect on the revenues of the Federal Barge Line, as joint rates remain effective from St. Louis *via* Cairo (the northern port when St. Louis is closed); and the shipper is not even cognizant that the river may be ice-bound from St. Louis to Cairo.

Limits of Discussion

In discussing the Great Lakes it is necessary to consider the canals and rivers connecting them as an integral part of one system. These rivers and canals being necessary for inter-lake communications, and connecting a series

of navigable lakes extending approximately 1 000 miles east and west, can not be considered therefore in the same category as the New York Barge Canal, which, in turn, is different from the Dismal Swamp Canal.

Exception might be taken to thus including the Welland Canal in treating connecting lake canals as integral parts of the Great Lakes System, because it is Canadian owned; but that does not affect operating conditions, except for tolls, and the United States could easily connect Lake Erie and Ontario as cheaply as Canada did. Without entering into any argument relative to the merits of the all-American route *via* the New York Barge Canal to the sea *versus* the Canadian route, it is feasible to discuss actual existing physical conditions, and demonstrate therefrom how utterly different are the various costs of lake, river, and canal transportation.

In discussing canals, the New York Barge Canal will be taken as typical, because it is the longest and best equipped canal in the United States, and of the greatest potential National importance. The operating costs there will be higher, of course, than on a canal free from locks.

Discussion of rivers will be confined to the Lower Mississippi, which is open for twelve months each year, and is, so far as operations are concerned, the most available in the United States.

One point needs emphasis—this discussion being solely to determine comparative costs deals only with the best existent type of channel in each case. Further, it is assumed that certain conditions, which do not now exist, will eventually exist, in order to arrive at what will be the eventual cost per ton-mile when the situation is practically perfected.

Type of Equipment Discussed

The many lake lines have various equipment, depending upon the service in which they are engaged. At least one line has self-propelled barges capable of navigating both the Great Lakes and the New York Barge Canal. Generally speaking, self-propelled barges for bulk cargoes on rivers and canals are uneconomical units. The New York Barge Canal and the Mississippi-Warrior Service also have different types of equipment, hence, to obtain comparative costs, an operating season for the most practicable single unit for each of these transportation lanes, will be studied. Such a comparison will assume the most favorable conditions possible for the three separate water avenues.

On the Great Lakes, take a 16 000-ton steamer having an average speed of 10 miles per hour, plying between Cleveland, Ohio, and Duluth, Minn., and capable of carrying coal from Cleveland to Duluth and iron ore in the reverse direction. Its cost would be approximately $1 500 000. Return on this cost at 6% plus 3% depreciation will be $135 000 per annum; this is the amount that must be earned in 8 months to yield a reasonable return.

On the New York Barge Canal, assume a unit consisting of a self-propelled barge, capable of carrying 300 tons of cargo, and pushing seven barges of 500 tons capacity each at an average of 5 miles per hour. This rate is used because a greater speed causes a very expensive wave wash, entering into cost of canal maintenance. Such a unit as used by the most efficient organization

now operating on the canal, could be built for about $400 000. Return and depreciation, as before, would here equal $36 000 per annum to be earned in 8 months to offer a reasonable return.

On the Lower Mississippi, assume a towboat and 8 barges capable of carrying 16 000 tons down stream, costing $650 000. The average speeds will be down stream 6 miles per hour and up stream 3 miles. The return of $58 500 per annum (9%) may require 12 months and still offer reasonable earnings.

Types of equipment actually used on the Mississippi River are shown in Figs. 1 and 2, including the method of towboat and barges taken as a basis for comparison.

Effect of Seasonal and Channel Differences

A lake steamer can carry the same tonnage in either direction, at about the same speed, without difficulty. The Barge Canal unit can never carry up stream the same tonnage as down stream, because there is always some current in the Mohawk, and sometimes it appreciably affects the carrying capacity. Normally, it should carry three-quarters as much.

The Lower Mississippi always has some current. A towboat which will successfully push 16 000 tons down stream at a certain speed can rarely make the same speed up stream with only one-half that total. Even then the cost of fuel up stream for the half cargo is approximately double that for the maximum, down stream.

Neither the Great Lakes System nor the Barge Canal will be subject to low water, but, at times, the canal will have to contend with very high water and strong current, while the Mississippi will be subject to such changes of high and low water that the carrying capacity of the fleet will be a variable. All these factors, it will be observed, will have an appreciable effect on the carrying cost per ton-mile of each unit.

The direct route varies in each instance. From Cleveland to Duluth, it is 810 miles; from Buffalo to Troy, N. Y., it is 341 miles and has 36 locks; from St. Louis to New Orleans by river it is 1 154 miles.

In order to strike a fair comparison the further assumption is made that the lake, canal, and river cargoes are delivered to the various units at one port of call. By thus reducing these operations to the simplest possible terms a definite cost basis results which is fair to all concerned; but even with this condition, due to the necessity of shifting barges for loading and unloading, the lake ship will save at least a day loading and a day delivering the same cargo.

Comparative Round Trip Costs

It will be instructive to follow the lake steamer. Exclusive of interest and depreciation, it costs about $325 per day to operate. Allow it 2 days at Cleveland for loading, 2 days at Duluth to unload, 2 to reload, and 7 days en route, or 13 days for the round trip. That would permit 19 round trips during the season of 8 months.

The actual running expenses for this would be $245 \times \$325 = \$79\,625$. With the necessary interest and depreciation, this would give a total of $214 625 annual income that such a ship must earn to operate successfully. Since

FIG. 1.—STEEL BARGE WITH 70 000 BUSHELS OF GRAIN, INLAND WATERWAYS CORPORATION.

FIG. 2.—STERN-WHEEL STEAMER AND TOW, MISSISSIPPI RIVER.

16 000 tons for a round trip of 1 620 miles would be 25 920 000 ton-miles, 19 trips per year would require 492 480 000 ton-miles; therefore, under these ideal conditions, such a ship must make approximately 0.44 mill per ton-mile, but it will be observed that this does not provide for overhead, insurance, accidents, etc. All these might require the addition of 0.4 mill per ton-mile, possibly 0.2 mill; so that it would be practicable for such a unit to operate quite successfully on 0.84 mill per ton-mile and, theoretically, even at 0.64 mill per ton-mile.

Similarly, on the New York Barge Canal, a unit would need 3 to 4 days at Buffalo to load, 6 to 7 days to unload and load at New York, 4 to 5 days down stream, and 5 to 6 days up stream, or an average round trip of 20 days. Lockage difficulties and delays account for these variables, allowing a total of 12 round trips per unit per season. Operating expenses of such a fleet aggregate roundly $192 per day. The actual expenses for this time would be (245 × $192) + $36 000 = $83 040, which is the actual return necessary to operate successfully.

Assume the load to be the same each way, although that up stream will normally average only three-quarters of that down stream, and the speed up stream will vary. The total traffic will be 3 800 tons × 341 miles × 2 × 12 = 31 099 200 ton-miles per year.

Therefore, under these ideal conditions, such a unit must make 2.7 mills per ton-mile to earn a living revenue, and allowing the same 0.4 mill per ton-mile for contingencies, as for the lake unit, the canal unit can operate successfully on 3.1 mills per ton-mile. Actually, its contingent expenses ought to be covered by 0.3 mill per ton-mile, so, theoretically, it ought to operate successfully for 3 mills per ton-mile.

On the Lower Mississippi, with the same time allowance as for the lake unit, namely, 6 days for loading, unloading, and reloading, with a round trip, St. Louis to New Orleans, of 2 308 miles, and with an average speed of 4 miles per hour, the actual running time would be 24 days. This would give 30 days per trip and 12 trips per annum. It must be assumed under general conditions, that the maximum down-stream tonnage will be 16 000, while the up-stream maximum will be 8 000, giving an average of 12 000 tons. River conditions, however, as shown by Government records, would reduce the yearly average to 6 000 tons per trip. Both high and low water appreciably affect the tonnage and speed.

The actual expenses of this operating fleet would be $430 per day, and the total for the year would be $430 × 365 = $156 950. To this must be added the carrying cost of $58 500 per annum, making a total of $215 450 necessary to yield a reasonable return. Then, 6 000 tons × 1 154 miles × 2 trips each way × 12 round trips = 166 176 000 ton-miles; and $215 450 ÷ 166 176 000 = 1.3 mills per ton-mile. Add to this the same 0.4 mill per ton-mile to cover expenses not otherwise provided for (this is the actual cost on the Mississippi), and it is found that such a unit on the Lower Mississippi could operate successfully for 1.7 mills per ton-mile. At its maximum carrying capacity this 0.4 mill per ton-mile could easily be reduced to 0.2 mill, and successful oper-

ation be carried on at 1.5 mills per ton-mile. The direct operating cost would also be reduced.

Summing up, a theoretically successful operation by lake could be carried on with an operating income of 0.64 mill per ton-mile; on the Lower Mississippi, with one of 1.7 mills per ton-mile; and on the New York Barge Canal, with one of 3 mills per ton-mile.

While the difference in cost under these assumed ideal conditions on the Great Lakes and the Lower Mississippi is 1.06 mills per ton-mile, yet when this is applied to the 166 176 000 ton-miles on the Lower Mississippi, it adds a total of $176 146.56 per annum to the gross income necessary to operate at a fair profit.

Such an itemized estimate of the theoretical incomes necessary to operate successfully upon the three types of lake, canal, and river channels under ideal conditions, is necessary because in most public discussions ardent waterway advocates point to lake costs as the ultimate cost by river, and the opponents of waterways point to the Erie Canal as the great failure whereby river transportation should be judged. As has been shown, neither of these is a correct assumption; nor is it correct to group the three together as a whole. So much for the ideal situation. The next question concerns the actual conditions under which rivers and canals may be utilized.

Private, Contract, and Common Carriers

Lakes, canals, and navigable rivers can be utilized by private, contract, or common carriers. The cost of operation of these three carriers, and their value to the public, increase in the order named.

The utilization of navigable streams by private and contract carriers alone does not justify the expenditures of the money of all the people for their creation. Indeed, if such utilization were the sole purpose of public construction, a large part of the people would be unjustly taxed for the benefit of a few who would reap the advantages.

Any thinking man must realize that the utilization of streams by private and contract carriers alone may lead to serious consequences, so that to extend fully the benefits to all the people who have been taxed to create them, to offset the serious menace to National prosperity that such utilization alone may lead, these private and contract carriers must be supplemented by powerful and efficient common carriers. This is not to be assumed as decrying the fullest possible utilization of streams by private and common carriers; rather it will be pointed out how the menace of such utilization can be absolutely neutralized by powerful and efficient common carriers, and how such joint utilization will result in the greatest good for the greatest number.

The private carrier requires the least organization and operates purely by water. It can balance its freight savings against the cost of operation and if the freight savings are the larger of the two, it can be said to be a successful carrier.

The contract carrier may operate purely by water or by water and rail. It has comparatively small overhead. As a water operator, pure and simple, it has no offset against its cost of operation, because the freight saving does not

accrue to it, and it has to have a gross income larger than its gross expenses to operate at all. If it has any relations with railroads, they are limited and simple, and it avoids the tremendous overhead of the common carrier.

If the common carrier is a carrier by water only, it still has expenses which a private or contract carrier does not have, because it needs organizations at each port touched by it. The private or contract carrier may only have one port of origin and one of destination.

If the common carrier by water fulfills its highest function of serving all the people, it must have a large overhead and this overhead is fixed by its activities, not by the size of its fleet. In other words, the overhead of such a common carrier is scarcely any greater if the fleet be doubled.

Value of Three Types

One of the dangers of the utilization of navigable streams and canals only by private carriers which are big corporations, is that the construction of the fleets necessary to carry the tremendous bulk essential to economical operation involves such a large original investment of capital as few corporations can afford. Hence, those fortunate enough to be able to create and operate their own fleets, can transport their products cheaper than their competitors and undersell them, thus destroying healthy competition.

A contract carrier may be of great advantage, or a positive detriment, to a large portion of the country. To illustrate, if coal operators in Southern Illinois owned their own facilities for transporting coal cheaply to Minnesota, and did so, and sold it cheaper, every consumer of heat, gas, light, and other power served by the "Twin Cities" would be benefited. If such coal operators, in addition, contracted to carry back ore from the Mesabe Ranges in Minnesota, their cost of transporting their own coal would be cheapened, the user of ore for manufacturing purposes would be benefited, and if the manufactured article bore a proportionate decrease in price to the decreased transportation costs, vastly more people would be benefited.

On the other hand, suppose a contract exists between certain grain dealers in, say, Kansas City and Omaha, a railroad connecting with St. Louis, which owns its own elevator, and a contract river carrier. If this railroad guarantees to maintain its elevator full enough of these particular operators' grain to keep the water carrier busy, and if the water carrier transports only for these particular operators, the combination can practically set the purchase price of grain in Kansas City and Omaha. Not only can it cripple all other grain operators who have to depend upon all-rail rates, but it can compel the farmer who sells to their competitor to accept a lower price for his grain, because he has to deduct from his purchase price the higher cost of transportation. However, if there exists in competition with such private and contract carriers, a great common carrier, offering to all the people the same facilities that the others offer to a few, and at the same price, there is no chance of the private and contract carriers creating a monopoly that will throttle competition.

Broadly speaking, the conditions precedent to the success of a great common carrier are not necessarily present for the success of a private or contract carrier. At the same time, to extend the benefits of cheaper water transportation on inland rivers and canals to all requires the utilization of

great common carriers. To create these conditions precedent to success it has been found necessary to have a governmentally owned corporation, functioning as a private corporation, but backed by the great powers of the Government itself. Railroad opposition had been successful in practically annihilating common carriers on navigable streams and lakes.

A private carrier requires:

(*a*) A suitable navigable river.
(*b*) Suitable boats.
(*c*) Terminal facilities, which may be very simple, suitable for handling only one commodity.
(*d*) A small operating force.

A contract carrier requires in addition:

(*a*) Terminal facilities, which are more complicated than those necessary for handling one commodity only.
(*b*) An operating force probably one-half greater than a private carrier.

A common carrier, to be of nation-wide benefit, must have in addition to the requirements of both the private and contract carrier:

(*a*) Balanced freight.
(*b*) Terminal facilities, dependent upon conditions in each locality both ashore and afloat; and more of them.
(*c*) Interchange with other carriers.
(*d*) Equitable division of revenue accruing from joint rail-water haul.
(*e*) A very large operating, traffic, and auditing overhead.

What follows refers to a great common carrier of nation-wide benefit, and not to a common carrier by water alone. These latter are highly desirable, but of no great National benefit.

A great common carrier must be organized along the lines of good railroad practice, must have as keen a traffic and operating manager, and other officials, as any railroad organization, and must be as closely co-ordinated through an executive as are the various divisions of a railroad. In order to be successful, it must also have much and costly equipment and powerful financial backing.

A demonstration by the present fully empowered governmental body (Inland Waterways Corporation) has been considered as necessary by Congress until such time as conditions precedent to success are established and private capital is willing to invest in an operation no longer hazardous. From this standpoint the experience of the Corporation with its Barge Line is instructive.

Inland Waterways Corporation Operations

Freight transported by common carriers is carried under what are known as class and commodity rates. These class rates vary considerably, for example, the first, second, third, fourth, and fifth class rates *via* the Barge Line from Minneapolis to East St. Louis, Ill., are, in cents per hundred pounds, 77, 63½, 51, 36½, and 26; whereas the similar rate on export grain from St. Louis to New Orleans is only 11½ cents.

Relative to the actual operations of the Inland Waterways Corporation, Table 1 provides a basis upon which calculations regarding the economics of water transportation may be made. Its practical value is enormous, and furnishes a mark "to shoot at" in getting a reasonable ratio between cost of operation and accruing revenue.

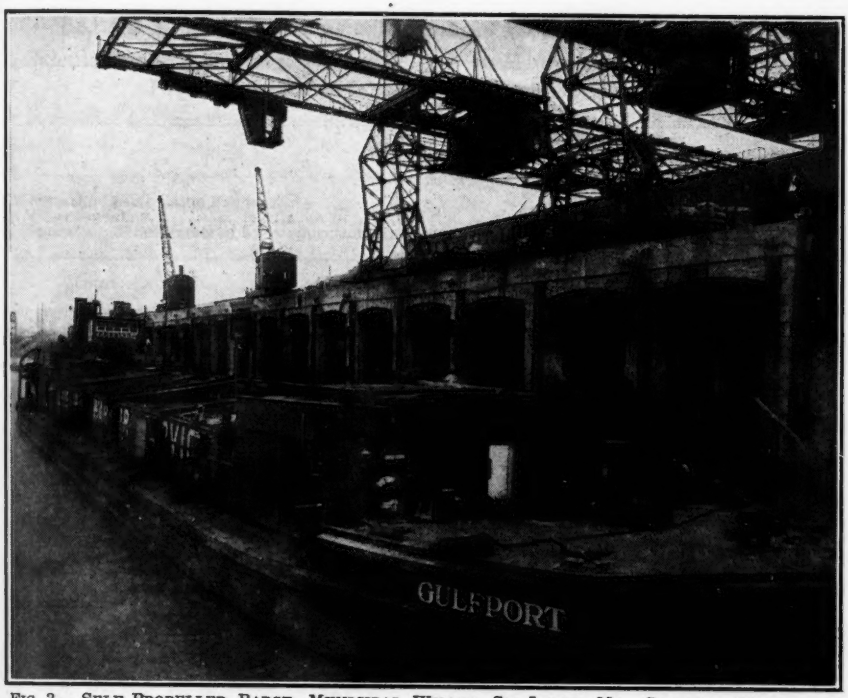

FIG. 3.—SELF-PROPELLED BARGE, MUNICIPAL WHARF, ST. LOUIS, MO., SHOWING METHOD OF LOADING AND STOWING FREIGHT.

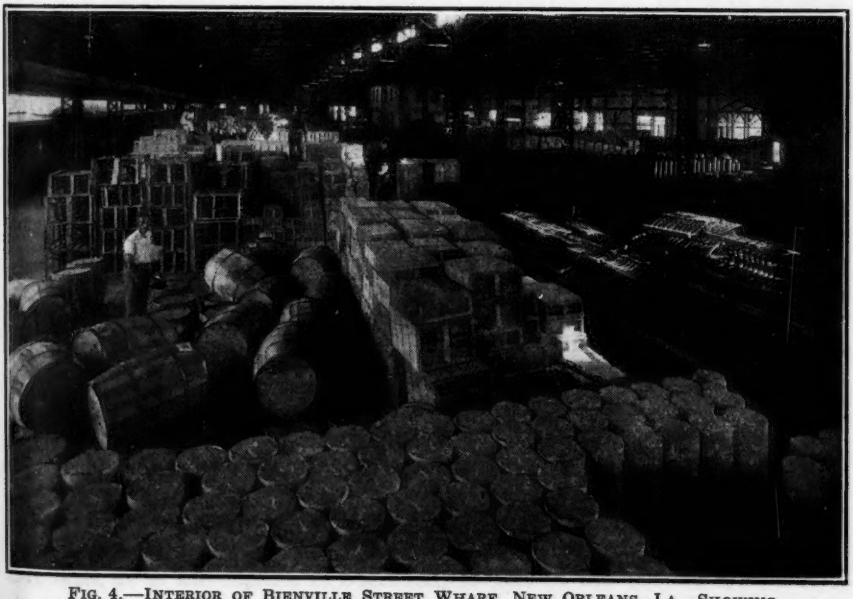

FIG. 4.—INTERIOR OF BIENVILLE STREET WHARF, NEW ORLEANS, LA., SHOWING CLASSIFICATION OF FREIGHT.

TABLE 1.—THE BARGE LINE DOLLAR AS INCOME AND DISBURSEMENT.
(Calculated on the total revenues and total expenses of the Operating Divisions of the Inland Waterways Corporation.)

	1927.	1928.
Where the Dollar Came From:		
Total revenues	$0.997	$1.00
Operating deficit covered by corporation	0.003	.....
Total	$1.00	$1.00
Where the Dollar Went:		
Maintenance and operation, Line vessels	$0.439	$0.403
Maintenance and operation, terminals	0.407	0.393
Traffic expenses	0.045	0.041
General expenses	0.045	0.049*
Loss and damage	0.032	0.029
Maintenance and operation, railroad	0.021	0.021
Charter expenses	0.011	0.005
Net income	.....	0.059
Total	$1.00	$1.00

* The increase in general expenses of 1928 over 1927 of 4 mills in the dollar was due to: (*a*) Higher cost of insurance due to tonnage increase and greater protection; (*b*) salaries and expenses of upper river officials; and (*c*) increased office rent and expenses at New Orleans.

As will be observed the maintenance and operation of terminals comprise 39.3% of the total costs of operation. That is because the terminal facilities, generally speaking, are owned by the cities in which they are located, and the Barge Line not only operates and maintains them, but pays 15 cents (in one case, 20 cents) for every ton of freight handled over them. The erection of these terminals by the various cities was essential to promote that co-operation between them and the Barge Line so necessary to build up a profitable freight-carrying business. Of course, the city is stimulated and encouraged to utilize the terminals as much as possible to get a greater revenue, and this 15 cents per ton is supposed to be sufficient to take care of the interest on the bonds, pay taxes, and amortize the investment. For example, in 1928, the City of Memphis received an approximate total of $50 000 for the use of its terminal, and the Barge Line kept it in repair. As traffic increases, this annual payment increases. This is the answer to the public statement so frequently made that the tax-payer is being mulcted by the Barge Line to pay for terminals. The amount of local freight that passes over these terminals is small compared to the interchange freight, and while the city is being reimbursed for its original expenditures, it has been helping those in the hinterland to save money on freight bills, and thus increase their purchasing power, which purchasing power is directly reflected in the city's prosperity.

Originally, no attempt at standardization of the type of terminals was made, nor could it be made. There were no standard barges, and no data available as to the expense of operating, so that in the existing system may be found the direct-lift, escalator type, and the inclined railroad with floating

terminal. In the operation of terminals there is thus an essential difference between rail and water transportation. Figs. 3 and 4 show the appearance and the operation of two of the terminals in use on the Mississippi River.

Interior water transportation has inherent advantages and equally inherent disadvantages when it comes to the question of reflecting savings to those not fortunately located on navigable streams. The physical nature of waterways limits the ports at which tows may touch or cargo be received, but rail or motor transportation has no such limitation. There thus results in Barge Line operations a costly transfer from car or truck to barge, or *vice versa*; and sometimes a second costly transfer, where the freight originates on a rail line, is transferred to barge, and again to rail as, for example, on a shipment from Chicago to Houston, Tex. Here, the freight moves by rail to St. Louis, is transferred to barge, and re-transferred from barge to car at Baton Rouge, La. These costs of transfer must be absorbed in rail-water-rail transportation; and still the resultant cost of the movement must be less than the all-rail movement. Otherwise, there is no virtue in such a form of transportation.

A shipper by rail can put his freight in a car at Chicago, and it will move through to destination without change of container, so that by a joint rail-water-rail route two transfers are introduced which are unnecessary in all-rail movements, but which cannot be obviated in joint movements. When the point of origin and the destination are river ports, and the same barge can carry its cargo from point of origin to point of destination then, and then only, can water transportation offer a comparable service to an all-rail service.

If it be necessary, as it now is, to transfer cargo moving between upper and lower river points, there is introduced a burdensome cost. Good business practice demands that this should be eliminated, but it could not be done as long as one fleet was designed to operate on a 4-ft. channel and the other on a 9-ft. channel.

It is to be noted that the costs of these transfers must be absorbed in the joint rail-water-rail rates, lower than all-rail rates, or the public will receive no advantage from such joint rates.

A Successful Policy

The whole National policy of rendering streams navigable, upon which so much money has been spent and will be spent, was based on the hope that by their utilization cheaper transportation would result. The Inland Waterways Corporation, a Congressional agent, was organized for the purpose of demonstrating that this policy is not a colossal failure.

It safely may be said that the demonstration has convinced the people of the United States that the policy of Congress, far from being a great mistake, has been the result of far-sighted vision; and the people themselves have demanded further and further expansion of the operations of this Corporation. They have seen its practical effects—cheaper transportation for all through co-ordination of rail, water, and motor transportation, with an accruing revenue to the joint carriers which, when fairly divided, will afford each participating carrier a reasonable living revenue.

RAILWAYS VERSUS WATERWAYS: AN ECONOMIC COMPARISON

By L. D. Cornish,* M. Am. Soc. C. E.

Synopsis

The purpose in preparing this paper has been to assemble authoritative facts relative to past rail and waterway traffic in a form convenient for study and analysis so that conclusions or opinions relative to the economics of present and future railway and inland waterway transportation could be subjected to the acid test of a fair comparison with past records of freight transportation upon the railroads and waterways of the United States.

The essential railway statistics from 1890 to 1924, inclusive, were assembled in graphic form in 1926, and on the theory that the past trend is the most probable indication of the trend in the near future, the demands of transportation and railway requirements to meet them are forecasted to the year 1950. It is shown that the railways during the 25-year period must expend approximately $11 000 000 000 for freight capital cost of additional transportation facilities.

The cost of completing the Mississippi Valley Inland Waterways System and providing thereon floating equipment and terminals for 60 000 000 000 ton-miles of traffic is developed from known costs and shown to be $600 000 000. It is shown that equivalent railway facilities will cost more than three times as much.

The past growth of waterway transportation is developed and forecast to 1950, and it is shown that the completion and utilization of the Mississippi Valley System by that time will be of economic benefit to the amount of more than $90 000 000 per annum.

Forecasts and future requirements are based on statistics to 1925, but the graphs and tables are brought as nearly up to date as published data would permit and serve as a check and confirmation of the original predictions.

Introduction

The history of mankind shows conclusively that the predominating influence in the rise and fall of nations and cities has been the relative cost of transportation. The life of nations has been, and still continues to be, a life of warfare—if not the warfare of bloody battlefields, it is the bloodless warfare of trade and commerce, which begets real conflict.

Bacon said: "There be three things which make a nation great and prosperous: A fertile soil, busy workshops, and easy conveyance for men and commodities from one place to another." The easy conveyance of commodities in these and future days means cheap transportation facilities. In the United States the ease of transportation is now measured by freight rates in mills per ton-mile.

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In 1924 the railroads of the United States transported 392 000 000 000 ton-miles of freight at an average rate of 11.32 mills per ton-mile. In the same year the report of the St. Marys Falls Canal shows lake shipments of 72 000 000 000 ton-miles at 1.2 mills per ton-mile. In six years, 1923 to 1928, the Government Barge Line on the Mississippi River between New Orleans, La., and St. Louis, Mo., transported more than 6 000 000 000 ton-miles of freight for an average revenue of 3.90 mills per ton-mile. This economy of water transportation is impressive. Coupled with the appeal of the agricultural and manufacturing interests of the Middle West for lower freight rates to seaboard ports, it suggests the economic necessity of completing the improvement of the Mississippi River and its main tributaries for navigation purposes as soon as possible and of developing thereon a water-borne commerce at lower freight rates. Then, the products of the fertile soil of this region may compete in the markets of the world on a more profitable basis with similar products from Canada, the Argentine, and Russia. Then, the workshops of the region may again become busy manufacturing goods for the Pacific Coast and the Orient. Thus, they may regain customers lost to them for years past on account of the advantage of the low freight rates by water *via* the Panama Canal possessed by their Atlantic Coast competitors.

Modern Waterway History

The Mississippi River, with its tributaries, comprises a natural waterway system more than 15 000 miles in length. About 5 000 miles, when the authorized improvements are completed, will constitute the trunk lines, reaching from Pittsburgh, Pa., to Kansas City, Mo., and from New Orleans to Chicago, Ill., and St. Paul, Minn. The area reached by these trunk waterways alone is so vast in extent, so rich in its products of agriculture, mining, and manufacturing, that the controversy over the relative economy of transportation by railroads *versus* inland waterways must inevitably be settled by actual operation with modern equipment upon modern waterways.

The movement for the development of the inland waterways of the United States appears to have run in cycles of about 20 years' duration, which have culminated in legislative authorization for the construction of one or more important waterways. During these cycles the persistent efforts of waterway advocates to educate the public and to secure legislative authorization for their projects have been as persistently opposed by interests which fear the competition of waterway transportation, or by persons who cannot, or will not, visualize the transportation needs of coming generations.

The waterway controversy which culminated about 1904 resulted in the construction of the New York Barge Canal and the Panama Canal. A barge, instead of a ship, canal across the State of New York was an economic mistake for which the selfish or misguided interests of the Cities of New York and Buffalo are solely responsible. At the time, waterway advocates and engineers were nearly unanimous in recommending a ship canal. This mistake has since been acknowledged by the effort of the State to have the Federal Government reconstruct part of the Barge Canal into a ship canal, instead of participating in the proposed St. Lawrence River improvement.

The Panama Canal has proved to be the wonderful military and commercial success which was anticipated by its advocates. Together, the high rail rates and the economic advantage which the Panama Canal gives to the Atlantic and Pacific Coasts are responsible for the unanimity of opinion of agricultural and manufacturing interests in the Middle West in favor of promptly completing the improvements of the Mississippi River and its tributaries for navigation purposes and of connecting them with the Great Lakes at Chicago. The cost of construction and maintenance and also the operating efficiency of the Lakes to the Gulf Waterway are dependent on a diversion of water from Lake Michigan at Chicago through the completed Chicago Sanitary Canal, thence through the Illinois Waterway, now under construction by the State of Illinois, the Lower Illinois River, and the Mississippi River.

Opposition to Waterways

A subtle, persistent, and effective opposition to the Illinois Waterway has existed for forty years among the interests naturally opposed to waterways in general and to this waterway in particular. The diversion question is limited to this particular part of the inland waterway system of the Mississippi Valley and may be dismissed as having only a minor influence on the relative economic importance of railroads and inland waterways in solving the future transportation problem of the United States.

The opposition to the development of waterways for transportation purposes is in the main from two classes, namely, railroad officials, or interests, and professional economists. The arguments of the railroad class are naturally biased by its concern as to the possible effect water transportation might have on its income and net earnings. Both classes are deeply perturbed at what they call the economically unsound and commercially unfair policy of developing waterways at public expense, and usually point out some particular waterway as a horrible example because of its small tonnage as compared with the large annual exependitures charged against it.

Conclusions relative to waterways in general are worthless if based entirely upon the results obtained from a study of isolated examples. Opponents of the improvement of waterways seldom, if ever, give any consideration to the total future transportation needs in such a rapidly growing country; nor will they admit the economic necessity of any section of the country being given lower freight rates than other sections in order to have a fair chance in competition for a profitable existence.

The Transportation Problem

Railroads are and probably always will be the principal National agencies of transportation, but the rapidly increasing demand for transportation coupled with the periods of rail-traffic congestion and demoralization during past years, gives rise to several questions relative to the expected status of the National transportation problem twenty years hence, or, say, by 1950.

The principal questions are as follows:

(*a*) What will be the probable transportation demand upon the railroads of the United States in 1950?

(*b*) What will be the cost of additional railroad trackage and equipment required to supply the probable increase in transportation demand?

(*c*) How much of the transportation demand can be supplied by inland waterways now authorized, but uncompleted?

(*d*) What will be the probable cost of providing inland waterway transportation facilities, terminals, and operating equipment?

(*e*) What will be the relative benefit to the public for freight shipments by rail or inland waterways?

Demand and Cost of Increased Traffic

Railroad Traffic Data.—The questions as to the growth of transportation and its cost depend upon such a complexity of circumstances and conditions so difficult to forecast that the best solution lies in assuming that the trend of transportation progress in the United States during the past forty years will continue for the next twenty years.

The Annual Reports of the Interstate Commerce Commission on the "Statistics of Railways in the United States" contain tabulated transportation statistics for all railroads and for each Class I railroad. In order to simplify the visualization of certain statistics the data have been plotted as shown in Figs. 5 to 8. In each case the solid lines show the data as given in the reports, and the broken-line continuations indicate the writer's opinion as to the probable future trend to 1950. The various graphs are lettered for convenience and the results indicating the expectancy in the several items by 1950 are given in Table 2, together with reference to the source of information.

TABLE 2.—United States Railroad Data Projected to 1950.

Curves.	Item.	Probable amount by 1950.	Reference, Interstate Commerce Commission reports.
A	United States population, in millions	150	
B	Traffic, all roads, in billions of ton-miles	870	1924, p. XCV
C	Freight density, in millions of ton-miles per track-mile	1.6	1924, p. XXXIX
D	Track length, total, in thousands of miles	555	1924, p. XCII
E	Length, main track, in thousands of miles	355	"
F	Length, yards and sidings, in thousands of miles	200	
Ff	Length, yards and sidings, in percentage of total	36	
G	Average capacity, freight cars, in tons	53	1924, p. XCII
H	Average load, freight cars, in tons	23	1924, p. XCVI
I	Travel of freight cars per annum, in thousand of miles	12 2	1924 pp. XCVI, XCII
J	Work of freight cars per annum, in thousands of ton-miles	281	
K	Total number of cars, in millions	3.1	1924, p. XCII
L	Aggregate car capacity, in millions of tons	164	
M	Average locomotive tractive capacity, in tons	31	1924, p. XCII
N	Total tractive capacity, in millions of tons	2.4	1924, p. XCII
P	Number of locomotives, in thousands	78	
S	Total capital cost, in billions of dollars	33.7	1924, p. XCIII

In Curve *B* (Fig. 5) the prolongation of the mean curve answers Question (*a*) by indicating 870 000 000 000 ton-miles as the expected traffic by 1950. This is more than double the traffic of 1925, and it will undoubtedly require huge expenditures of capital to provide additional tracks, yards, and equipment. Curve *C* (Fig. 5) shows the density of traffic and indicates the average

efficiency of the railroads with respect to their freight movement. A scrutiny of the records for individual roads develops an amazing variation in this measure of railroad performance and shows that an average of more than 1 000 000 ton-miles per track-mile is due to the coal-carrying roads of the Eastern and Southern Districts.

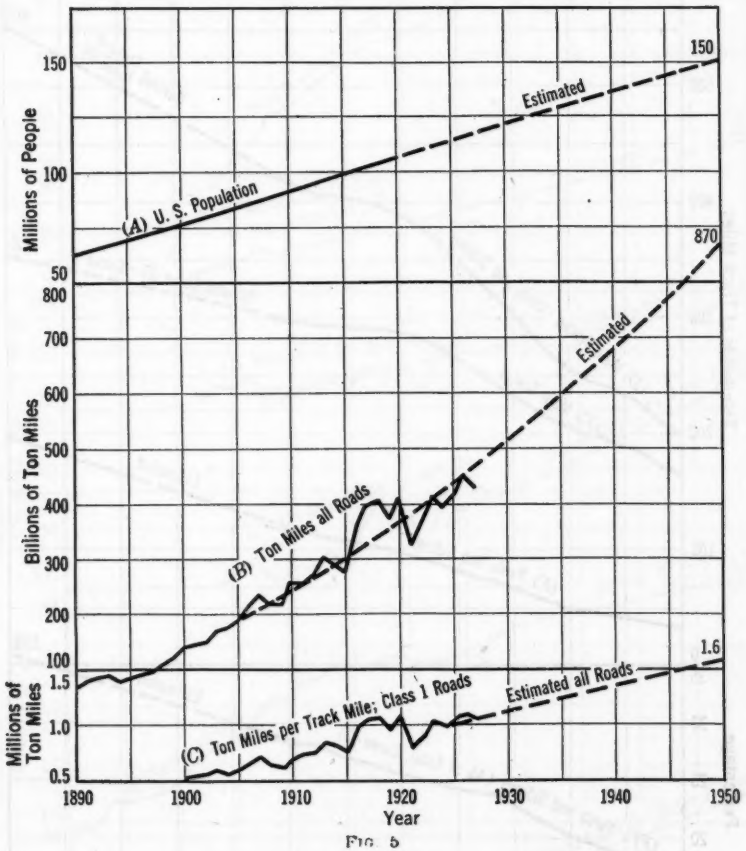

FIG. 5

Track Requirements.—Curves *D* and *E* (Fig. 6) were not directly extended because of the change of trend in recent years. New trackage requires heavy expenditures of new capital. During and immediately following the World War new capital was almost unobtainable, and the railroads were forced to provide for the unprecedented traffic demand by improving their operating efficiency. This resulted in a cessation of main-line track construction and disrupted the trend of Curves *D* and *E*. However, the construction of new track for yards and sidings had to be continued, as shown by Curve *F* (Fig. 6), and this provides a method for forecasting main-track requirements and for projecting Curves *D* and *E*.

Curve *F* shows a remarkably uniform trend of yard and siding construction which apparently is not much affected by periods of business depression or difficult financing. Therefore, this curve may be prolonged to 1950 (Fig. 6) with reasonable accuracy.

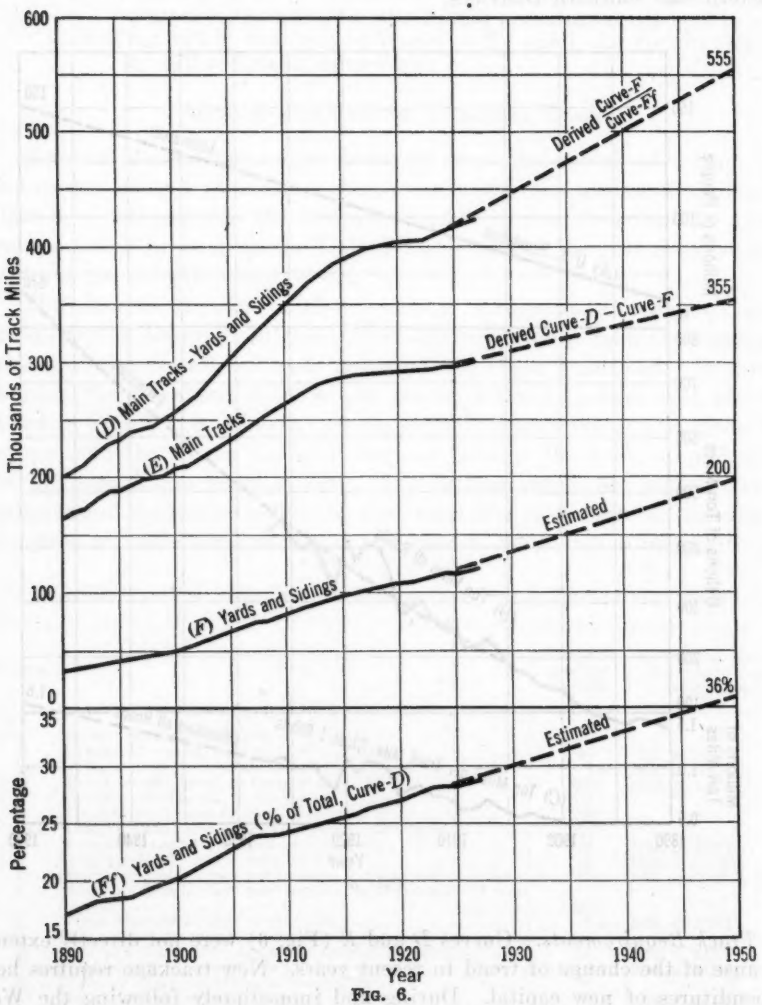

FIG. 6.

Curve *Ff* (Fig. 6), prepared to show what percentage of all tracks is in yards and sidings, also shows a steady increase. Prolonging its definite trend indicates that by 1950 about 36% of all tracks will be in yards and sidings. Since both curves, *F* and *Ff*, seem reasonable and consistent as projected to 1950 their relation to one one another should hold true. This will give the projection of Curve *D* to about 555 000 miles by 1950.

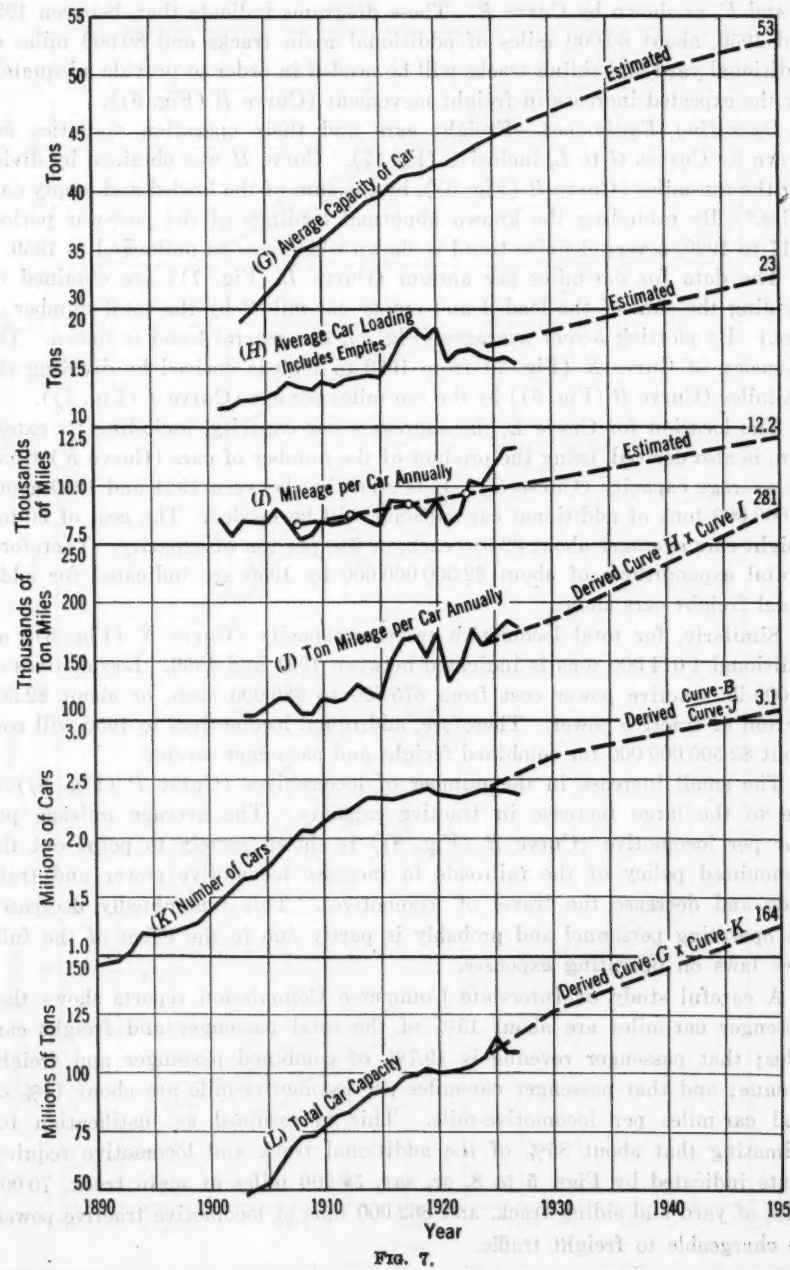
Tons
(G) Average Capacity of Car
Estimated
53
23
(H) Average Car Loading Includes Empties
Tons
Thousands of Miles
(I) Mileage per Car Annually
Estimated
12.2
281
Derived Curve H x Curve I
Thousands of Ton Miles
(J) Ton Mileage per Car Annually
Derived Curve-B / Curve-J
3.1
Millions of Cars
(K) Number of Cars
164
Derived Curve-G x Curve-K
Millions of Tons
(L) Total Car Capacity
Year

FIG. 7.

The main-line trackage needed then becomes the difference between Curves *D* and *F*, as shown by Curve *E*. These diagrams indicate that, between 1925 and 1950, about 60 000 miles of additional main tracks and 80 000 miles of additional yard and siding tracks will be needed in order to provide adequately for the expected increase in freight movement (Curve *B* (Fig. 5)).

Operating Equipment.—Freight cars and their operation statistics are shown by Curves *G* to *L*, inclusive (Fig. 7). Curve *H* was obtained by dividing the ton-miles (Curve *B* (Fig. 3)), by the sum of the loaded and empty car-miles.* By excluding the known abnormal loadings of the post-war period, 1917 to 1920, a very definite trend is shown which can be prolonged to 1950.

The data for car-miles per annum (Curve *L* (Fig. 7)) are obtained by dividing the sum of the loaded and empty car-miles* by the total number of cars.† By plotting 5-year averages (Fig. 7), the general trend is shown. The extension of Curve *K* (Fig. 7) from 1930 to 1950 is derived by dividing the ton-miles (Curve *B* (Fig. 5)) by the ton-miles per car (Curve *J* (Fig. 7)).

The location for Curve *L*, the aggregate car capacity, including its extension, is also derived, being the product of the number of cars (Curve *K*) times the average capacity (Curve *G*). It is seen that between 1924 and 1950 about 57 000 000 tons of additional car capacity will be needed. The cost of 50-ton freight cars averages about $2 000 each, or $40 per ton of capacity. Therefore, capital expenditures of about $2 300 000 000 by 1950 are indicated for additional freight cars alone.

Similarly, for total locomotive tractive capacity (Curve *N* (Fig. 8)) an additional 1 014 000 tons is indicated between 1924 and 1950. Locomotives of 60 000-lb. tractive power cost from $75 000 to $80 000 each, or about $2 500 per ton of tractive power. Therefore, additional locomotives to 1950 will cost about $2 500 000 000 for combined freight and passenger service.

The small increase in the number of locomotives (Curve *P* (Fig. 8)) is due to the large increase in tractive capacity. The average mileage per year per locomotive (Curve *R* (Fig. 8)) is shown merely to point out the pronounced policy of the railroads to increase locomotive power and train loads and decrease the travel of locomotives. This undoubtedly decreased the operating personnel and probably is partly due to the effect of the full-crew laws on operating expenses.

A careful study of Interstate Commerce Commission reports shows that passenger car-miles are about 13% of the total passenger and freight car-miles; that passenger revenue is 19.7% of combined passenger and freight revenue; and that passenger car-miles per locomotive-mile are about 14% of total car-miles per locomotive-mile. This is assumed as justification for estimating that about 85% of the additional track and locomotive requirements indicated by Figs. 5 to 8, or, say, 50 000 miles of main track, 70 000 miles of yard and siding track, and 862 000 tons of locomotive tractive power, are chargeable to freight traffic.

* Rept., Interstate Commerce Comm., 1924, p. XCVI.

† *Loc. cit.*, p. XCII.

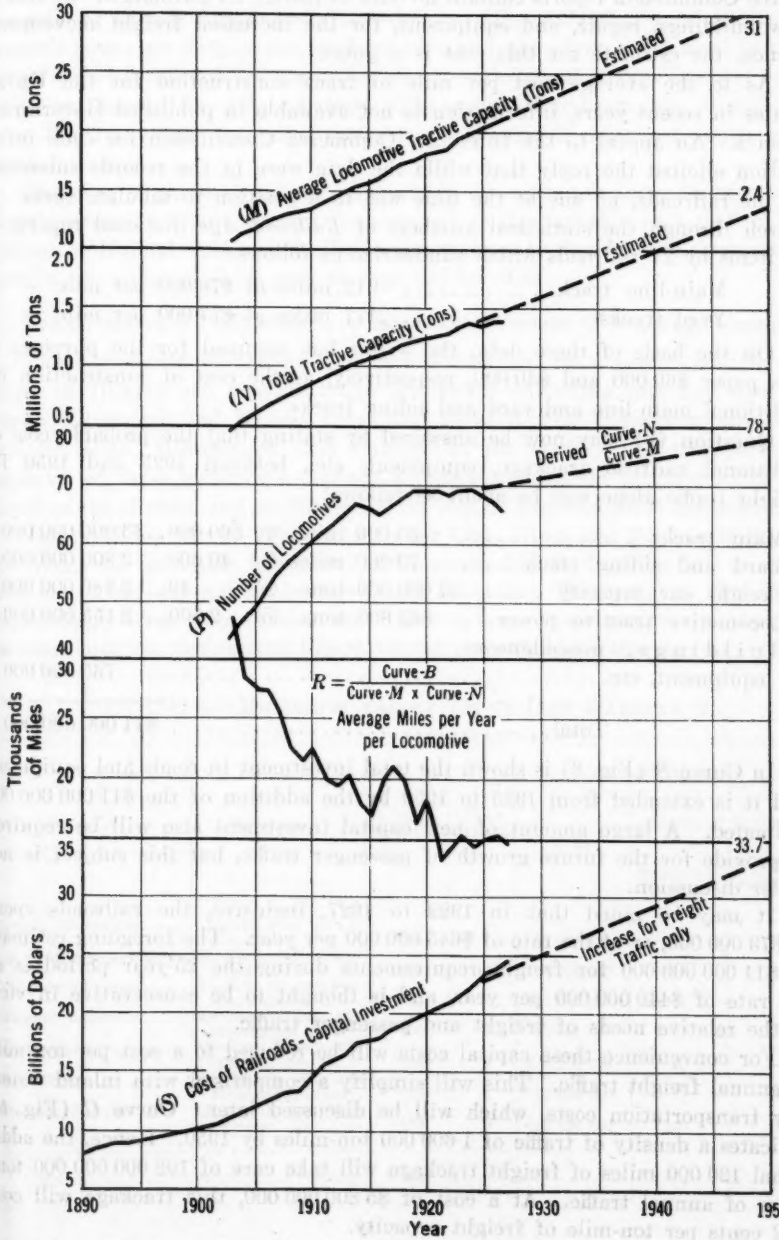
Tons
30
25
20
15
10
(M) Average Locomotive Tractive Capacity (Tons)
Estimated
31
2.4
Millions of Tons
2.0
1.5
1.0
0.5
(N) Total Tractive Capacity (Tons)
Estimated
80
70
60
50
40
Derived Curve-N / Curve-M
78
(P) Number of Locomotives
Thousands of Miles
30
25
20
15
$R = \frac{\text{Curve-}B}{\text{Curve-}M \times \text{Curve-}N}$
Average Miles per Year per Locomotive
35
30
25
20
15
10
5
Billions of Dollars
33.7
Increase for Freight Traffic only
(S) Cost of Railroads-Capital Investment
1890
1900
1910
1920
1930
1940
1950
Year

FIG. 8.

Capital Cost of Additional Railroad Requirements.—The Interstate Commerce Commission reports contain no data to justify an estimate of the cost of new buildings, repair, and equipment, for the increased freight movements. Hence, the estimate for this cost is a guess.

As to the average cost per mile of track construction for the United States in recent years, information is not available in published Government reports. An appeal to the Interstate Commerce Commission for such information elicited the reply that while the data were in the records submitted by the railroads, no one at the time was in a position to tabulate them. A search through the statistical numbers of *Railroad Age* disclosed reports of 43 items by 27 railroads which summarize as follows:

Main-line track	612 miles at	$76 000 per mile
Yard tracks	177 miles at	$77 000 per mile

On the basis of these data, the writer has assumed for the purposes of this paper $60 000 and $40 000, respectively, as the cost of construction for additional main-line and yard and siding tracks.

Question (*b*) may now be answered by stating that the probable cost of additional railroad trackage, equipment, etc., between 1925 and 1950 for freight traffic alone will be about as follows:

Main tracks	50 000 miles	@	$60 000..	$3 000 000 000
Yard and siding track	70 000 miles	@	40 000..	2 800 000 000
Freight car capacity .....57 000 000 tons		@	40..	2 280 000 000
Locomotive tractive power...	862 000 tons	@	2 500..	2 155 000 000
Buildings, miscellaneous equipment, etc.....				765 000 000
Total.....				$11 000 000 000

In Curve *S* (Fig. 8) is shown the total investment in roads and equipment and it is extended from 1925 to 1950 by the addition of the $11 000 000 000 estimated. A large amount of new capital investment also will be required to provide for the future growth of passenger traffic, but this subject is not under discussion.

It may be noted that in 1922 to 1927, inclusive, the railroads spent $3 873 000 000, or at the rate of $645 000 000 per year. The foregoing estimate of $11 000 000 000 for freight requirements during the 25-year period is at the rate of $440 000 000 per year, and is thought to be conservative in view of the relative needs of freight and passenger traffic.

For convenience these capital costs will be reduced to a cost per ton-mile of annual freight traffic. This will simplify a comparison with inland waterway transportation costs, which will be discussed later. Curve *C* (Fig. 5) indicates a density of traffic of 1 600 000 ton-miles by 1950. Hence, the additional 120 000 miles of freight trackage will take care of 192 000 000 000 ton-miles of annual traffic. At a cost of $5 800 000 000, this trackage will cost 3.02 cents per ton-mile of freight capacity.

The 57 000 000 tons of additional car capacity (Curve *L* (Fig. 7)) are 35% of the total for 1950 and, therefore, the hauling capacity is 35% of

870 000 000 000, or 305 000 000 000 ton-miles. The cost of this additional car capacity was shown to be $2 280 000 000, which is at the rate of 7.5 mills per ton-mile of annual freight-carrying capacity. The 862 000 tons of additional tractive power are 36% of the total for 1950 and, therefore, the annual hauling capacity is 313 000 000 000 ton-miles, and the additional locomotive cost is 6.9 mills per annual ton-mile capacity. The cost of buildings, etc., distributed over 313 000 000 000 ton-miles amounts to about 2.5 mills per ton-mile of annual traffic.

The sum of these unit costs amounts to 4.7 cents per ton-mile of annual freight capacity. This amount is presented as the probable unit cost of providing additional railroad facilities adequately to handle the increase in freight ton mileage, which may be expected by 1950.

Transportation Possibilities of Mississippi Valley Waterway System

The completion of the projects now authorized by Congress and by the State of Illinois will provide trunk waterways extending east and west between Pittsburgh and Kansas City; and between New Orleans in the south and St. Paul, Minneapolis, and Chicago in the north. The transportation capacity of these waterways depends principally upon the reliable width and depth of the channel and on the size of the locks. The minimum width of these channels will be 200 ft. The locks on the Ohio River and Illinois Waterway are identical in usable horizontal dimensions, 600 ft. long by 110 ft. wide, and the minimum navigable depth will be 9 ft. The locks on the Upper Mississippi River vary in size and this has been given proper consideration in preparing the statistics of this waterway presented in Table 3.

TABLE 3.—Mississippi Valley Trunk-Line Waterways.

Stream.	Between.	Length, in miles.	Depth, in feet.	Annual Capacity.		
				Tons.	Billions of Ton-Miles.	
					Maximum.	1950 estimate.
Illinois Waterway	Chicago and Grafton, Ill.	325	9	60 000 000	20	10
Upper Mississippi River.	St. Paul, Minn., and Grafton, Ill.	670	6	20 000 000	14	4
Mississippi River	Grafton, Ill., and Missouri River	20	9	100 000 000	2	1
Missouri River	Kansas City, Mo., and Mississippi River	400	6	30 000 000	12	5
Mississippi River	Missouri River and Ohio River	105	9	100 000 000	10	4
Ohio River	Pittsburgh, Pa., and Mississippi River	970	9	60 000 000	52	10
Mississippi River	Cairo, Ill., to New Orleans, La.	970	9	150 000 000	100	26
Total		3 460			210	60

The estimated capacity by 1950 is materially less than that claimed by the exponents of each waterway and is listed to give a general idea of the trans-

portation possibilities of this waterway system. The total of 60 000 000 000 ton-miles may not be unreasonable in view of the probable growth of transportation in the territory served, provided proper water freight rates should be established. However, such a huge figure should not be considered without, at least, some investigation of the potential tonnage in the area served by these waterways.

According to statistics of the Interstate Commerce Commission report for 1924 the total ton-miles for 30 railroads serving the Mississippi Valley were more than 162 000 000 000. Several of the roads served other territories. After making allowances for these conditions, it was found that about 100 000 000 000 ton-miles might be assumed as within the Mississippi Valley, which comprises 65% of the area of the United States.

Based on the prospective increase indicated by Curve *B* (Fig. 5), an additional 120 000 000 000 ton-miles will materialize by 1950. It does not appear unreasonable to assume that the waterway system could take care of one-third this increase, or 40 000 000 000 ton-miles, equivalent to a water-haul of about 60 000 000 000 ton-miles. This is in view of the fact that the annual traffic of the Federal Barge Line alone on the Mississippi River now exceeds 1 000 000 000 ton-miles and the uncompleted Ohio River System produces in excess of 2 000 000 000 ton-miles.

Assuming 60 000 000 000 ton-miles per annum as the probable traffic demand available for this waterway system by 1950 raises the question as to whether the past growth of water transportation has been such as to indicate a future growth to a total of 60 000 000 000 ton-miles by 1950. The usual reply of waterway advocates to such a question is "provide a dependable completely improved waterway between important terminals and the operating equipment, terminal facilities, and tonnage will be developed." Such a statement is merely a prophecy and without supporting evidence is unconvincing. The writer believes that such a prophecy with regard to the Mississippi River System will eventually come true and that there now exists sufficient evidence in support of such a claim.

The past growth of waterway traffic for the entire Mississippi System cannot be shown, as so much of the system is incomplete and has no traffic. However, the tonnage statistics of all important waterways of the United States are available in public documents, giving the data shown in Table 4. The capacity of the Monongahela River is about 25 000 000 tons, hence, no further material increase may be expected until additional locks are provided.

The other waterways in Table 4 show an annual traffic increase of from three to five times the rate of increase shown by railroads. Such increases are remarkable; if they are maintained, the capacities of all these waterways would be reached in less than fifteen years.

The average annual rate of increase in tonnage for these waterways is 14.4 per cent. This rate, if maintained for a period of twenty-five years, would result in a tonnage and probably ton-mileage thirty-six times as great as in 1925. To those who would dispute the assertion that an annual increase of 15% in the next twenty-five years is not only possible but probable, it is pointed out that not one of the rivers in the Mississippi Valley is completely improved for navigation except the Monongahela River and the

Mississippi River below Cairo, and even the latter is subject to interruption of traffic for months at a time due to insufficient depth and width of its dredged channels.

TABLE 4.—Traffic on Certain Important United States Waterways.

Waterway.	Tonnage, 1919.	Tonnage, 1925.	Annual increase, percentage (100 R).*
Ohio River	5 000 000	15 737 015	21.1
Monongahela River	17 137 501	23 716 121	5.6
Allegheny River	2 058 069	4 744 843	15.0
Mississippi River Division: Federal Barge Line	109 218	910 755	42.0
Tennessee River	600 107	1 940 972	21.6
Erie Division, New York Barge Canal	673 000	1 945 466	19.4
Panama Canal	6 981 996	23 958 826	22.8
Total	32 559 891	72 953 998	14.4

* $R = \sqrt[n]{\frac{T}{t}} - 1$, in which, R equals annual rate of increase; N, number of years in period; t, tonnage for 1919; and T, tonnage for 1925. The percentage equals 100 R.

Until these rivers are completely improved, transportation upon them must be considered as in its infancy and, hence, subject to a rate of increase somewhat comparable to that of the early days of the Sault Ste. Marie ("Soo") Locks and the St. Marys Falls Canal in Michigan. As shown by Government reports, the freight passing through the "Soo" Locks in 1856 was 33 817 tons and, in 1880, it was 1 321 906 tons. This 25-year period shows 15.7% annual increase. In 1905, the tonnage was 44 270 680, equivalent to an annual increase of 15.1 per cent.

The "Soo" Locks are the bottleneck of the greatest inland waterway system of the world. They are frequently cited as an example so favored by Nature that no other waterway could be comparable with them as to tonnage possibilities. Yet neither for the first fifty years of their history, nor for any 6-year period subsequent to 1890, was the annual rate of tonnage increase as great as the rate for the waterways listed in Table 4, the Allegheny and Monongahela Rivers excepted. This certainly indicates that, since 1919, transportation interests, exclusive of Governmental, have been utilizing the principal unconnected and incomplete waterways of the Mississippi River System as fully as could be expected. Hence, the claim of opponents to waterway development that the public would not use them is without justification.

Those who so severely attack the policy of improving American waterways as uneconomical dwell at great length on the small volume of tonnage on certain of the waterways listed in Table 4. Such individuals lose sight of or ignore the power of compound interest.

For many years the New York Barge Canal has been a conspicuous and favorite object of attack, yet the main division of this canal, inadequate in size for modern transportation methods, shows an annual tonnage increase of 19.4 per cent. The Erie Division of the New York Barge Canal was designed for a maximum of 20 000 000 tons. The tonnage in 1925 was more than 1 900 000; hence, if the tonnage continues to increase for 25 years at one-

half the past rate of increase, or, say, 10%, the capacity of the canal will be reached by 1950.

The waterways of Table 4 show an average rate of increase in tonnage of 14.4 per cent. If the Monongahela River is excluded, the rate is 21.4 per cent. On Fig. 9 are shown graphically these annual tonnages. From 1925 the curves are extended to indicate prospective tonnage based on an annual increase of 10 per cent.

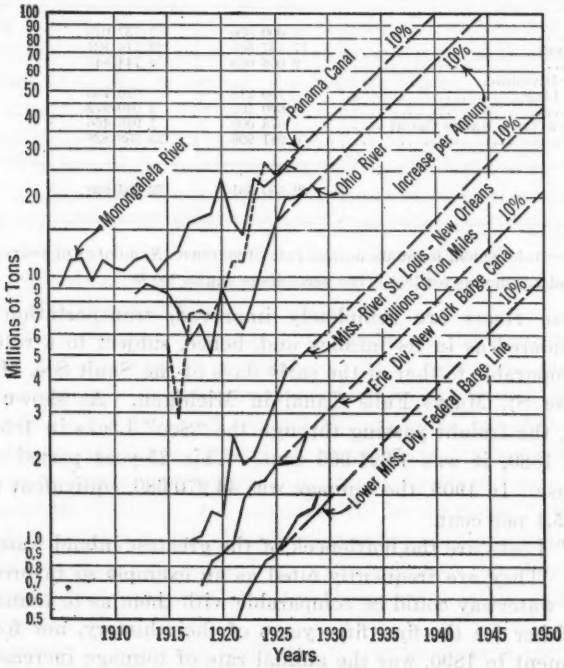

FIG. 9.—TONNAGE STATISTICS FOR UNITED STATES WATERWAYS.

There is also shown on Fig. 9 a record of the ton-miles of total traffic on the Mississippi River between St. Louis and New Orleans. The tonnage between the principal terminals—St. Louis, Cairo, Memphis, and New Orleans—is published each year in the "Commercial Statistics," volume of the reports of the Chief of Engineers. The 1924 report also gave the average haul in detail, from which the ton-mileage for 1923 was computed and it is, therefore, correctly shown. For other years the tonnage was combined with the average haul of 1923 to obtain the ton-miles as plotted. The error is probably small and on the conservative side as it is known that the increase in tonnage is largely on longer haul freight. Fig. 9 shows an annual increase of 18% between 1917 and 1926 and 28% for the years 1924 to 1926. If this particular curve is continued at a 10% rate, it reaches a probable ton-mileage of 44 000 000 000 by 1950.

It would seem that the requirements of conservatism would be sufficiently satisfied if 10% be taken as the annual rate on which to base the future

growth of transportation on the Mississippi River System. This rate will produce an eleven-fold increase in 25 years.

Government reports show that in 1925 the Ohio River System, exclusive of the Monongahela, carried more than 1 000 000 000 ton-miles. At 10% annual increase this would amount to 11 000 000 000 ton-miles for 1950.

Thus, the Mississippi below St. Louis and the Ohio below Pittsburgh should supply 55 000 000 000 ton-miles in 1950. It is reasonable to expect that new traffic on the Upper Mississippi and the Missouri augmented by that resulting from opening the Illinois Waterway about 1931, will produce enough traffic to increase the total well in excess of the 60 000 000 000 ton-miles by 1950 estimated in Table 3. On the basis of the foregoing discussion, the writer answers Question (*c*) by stating that the progress in waterway transportation from 1919 to 1925 justifies the assertion that by 1950 the inland waterways of the Mississippi and its tributaries can supply an equivalent amount, or 40 000 000 000 ton-miles of the expected railroad transportation demand of the Mississippi Valley.

Cost of Waterway Transportation Facilities

The costs of providing trackage and operating equipment for railroad transportation were based entirely upon the records of the Interstate Commerce Commission to eliminate as far as possible personal opinions. The following derivation of waterway costs, whenever possible, will also be based on Government data.

The best data on inland waterway costs are the annual reports of the Federal-operated Inland Coastwise Waterways Service which, in 1924, became the Inland Waterways Corporation. This Corporation and its predecessor have operated barge lines on the Warrior and Mississippi Rivers since 1919. The Warrior Division is still in the experimental stage and its operations are unprofitable.

The Mississippi Division hereinafter referred to as the Barge Line has shown steady and persistent progress whenever a proper navigable channel was available. The great variety of general freight carried by the Barge Line and its field of operations in the heart of the Mississippi Valley make it an ideal example for comparing inland waterways and railroads.

The Barge Line in 1925 transported 910 000 tons an average distance of 960 miles, or a total of 875 000 000 ton-miles. In 1925 its total investment in real property and equiment was $8 079 833.43, or at the rate of 9.24 mills per ton-mile of actual traffic.

This value is not a fair one for two reasons: First, the Barge Line uses municipally owned terminals, the cost of which should be considered; and, second, the line did not operate at its normal capacity because the channel was shallow and narrow for several months.

From data furnished by the Inland Waterways Corporation, Table 5 was prepared.

The writer finds that the 9 towboats are equivalent to 7½ standard towboats, each of which normally tows a cargo of 10 000 tons. These towboats at 20 000 miles per year, and normal cargo, could give 1 500 000 000 ton-

miles of service. Actually three of these towboats averaged in excess of 20 000 miles for twelve consecutive months and the entire towboat fleet averaged 19 400 miles for a fiscal year.* The towboat capacity in Table 5 was found to be 91% of what the capacity would be if assumed on the basis of actual performance by several towboats for continuous periods in excess of a calendar month, including all delays and lay-overs at port; also the estimate of barge capacity of 1 314 000 000 ton-miles was 69% of the capacity assumed on the basis of actual performance for a calendar month.

TABLE 5.—INLAND WATERWAYS CORPORATION, MISSISSIPPI DIVISION.

Item.	Practical capacity, in ton-miles per annum.	Replacement cost.	Cost per ton-mile, in mills.
U. S. terminals, harbor vessels, etc., municipal terminals used	2 600 000 000	{ $3 490 000 / $2 510 000 }	3.00
Nine towboats	1 500 000 000	2 810 000	1.87
Fifty-one barges	1 314 000 000	3 933 400	3.00
Three self-propelled barges	142 500 000	840 000	5.90

The Barge Line terminals and equipment are not balanced as to capacity. A balanced system may be as shown in Table 6.

This indicates 8 mills per ton-mile of capacity as the unit cost of providing terminals and operating equipment for a barge system for long hauls and a diversified class of freight, the lowest class being grain.

The unit cost of terminals would be higher for shorter haul business of the same class. However, it may be noted that the barge equipment of the Mississippi Division is of the covered compartment type, costing about $45 per ton of cargo capacity; whereas open barges as used on the rivers for coal, ore, lumber, sand, and gravel, cost less than $25 per ton of cargo capacity.

TABLE 6.

Item.	Normal capacity, in ton-miles.	Unit cost, in mills.	Total cost.
Terminals and harbor equipment	1 000 000 000	3.00	$3 000 000
Towboats	900 000 000	1.9	1 710 000
Barges	900 000 000	3.0	2 700 000
Self propelled barges	100 000 000	5.9	590 000
Total for System	1 000 000 000	8.0	.....
Total cost	.....	....	$8 000 000

To the unit cost of 8 mills for terminals and operating equipment must be added the unit cost for completion of the Mississippi River System as authorized by Congress and the State of Illinois. The U. S. Engineer Department estimates that $125 000 000 will complete all authorized projects in the

* Annual Rept., Inland Waterways Corporation, 1923, p. 52.

Mississippi River System. To this should be added $20 000 000 authorized by the State of Illinois to connect the Chicago Sanitary Canal with the Government-operated Illinois River at Utica, Ill., and $5 000 000 or less to provide a 9-ft. open channel in the Illinois River from Utica to Grafton and in the Mississippi from Grafton to Cairo. The total cost for the completion of this Waterway System may be placed at $150 000 000, which for the 60 000 000 000 ton-miles of expected annual traffic previously estimated would amount to 2½ mills per ton-mile.

Thus, on the basis of the foregoing estimates the cost of completing approved waterways and providing barge transportation facilities on the main arteries of the Mississippi Valley Waterway System and the Lakes-to-the Gulf Waterway (Question (*d*)) is found to be about 1 cent per ton-mile of annual traffic estimated for 1950.

Costs of Freight Transportation

The railroads being common carriers, the cost to the public of freight transportation by rail is established by published freight rates, as approved by the Interstate Commerce Commission. A different condition exists relative to waterways, due to the fact that the right of way or river channels are public waters which may be freely used by any or all, subject only to navigation regulations established by law. This condition, therefore, permits of three classes of carriers on waterways, namely, common, private, and contract carriers.

Common carriers, such as the Inland Waterways Corporation, have regular routes and schedules; they accept whatever business is offered by the public. Private carriers, on the other hand, are owned and operated solely for the benefit of their owners in transporting their own products. Among existing private carriers may be mentioned several coal companies on the Upper Ohio and Monongahela Rivers, the West Kentucky Coal Company operating on the Tennessee, Ohio, and Mississippi Rivers, the Carnegie and the Jones and Laughlin Steel Companies, and the Standard Oil Company, on the Lower Mississippi River and New York Barge Canals. Contract carriers, many of which have been operating for years on inland rivers, function similarly to the tramp freighters on the oceans.

The water common carrier, to be successful, must have joint rail-and-water rate agreements with the railroads. Hence, these rates are subject to the approval of the Interstate Commerce Commission. The Barge Line is the only water common carrier of consequence in the Mississippi Valley. Its rates, as authorized by the Commission, are made by deducting from the all-rail rate from point of consignment to point of delivery 20% of the all-rail rate from the Barge Lines' port of shipment to port of discharge. For example, at present, a Chicago company desiring to ship agricultural implements to New Orleans can utilize water shipments only between St. Louis and New Orleans, and its saving would be 20% of the $13.00 (St. Louis-New Orleans rate), or $2.60 per ton. The all-rail Chicago-New Orleans rate is $14.60 per ton; hence, the joint rail-water rate is $14.60 less $2.60, or $12.00 per ton.

In 1926, the Mississippi Division of the Barge Line handled 1 044 649 tons of freight on which the direct freight-bill saving to the shipper averaged $1.75 per ton, or a total saving of $1 828 135. All water carriers are free to set their purely all-water port-to-port rates without reference to the Commission. Hence, it may be expected that all-water rates will be governed by the necessities of competition.

The Barge Line has no competition at present and its "water rates, like all other transportation charges, are in the original instance made to secure as high revenue as the traffic will stand and develop." The high revenue, however, as charged by the Barge Line is 80% of the corresponding all-rail rate and the general shipping public saves the 20 per cent.

The future development of privately owned and operated water carriers must depend upon the profit to be gained in this line of business. The average profit or loss per ton of freight handled by the common carrier is the margin between the average operating cost and revenue. The annual reports of the Inland Waterways Corporation show in great detail the operating costs of the Barge Line, some of which are summarized in Table 7. Maintenance and depreciation is more than 10% of the property investment, which on December 31, 1927 amounted to $10 993 361.23. Neither taxes nor interest are paid as this is a Government-owned corporation.

TABLE 7.—Mississippi River Division Operating Cost and Revenue Per Ton.

Year.	1923.	1924.	1925.	1926.	1927.	1928.	Average.
Terminals:							
Operation	$1.52	$1.36	$1.41	$1.56	$1.42	$1.27	$1.42
Maintenance and depreciation	0.21	0.14	0.18	0.21	0.21	0.17	0.19
Vessels:							
Operation	1.11	0.96	1.01	1.02	1.05	0.84	1.00
Maintenance and depreciation	0.63	0.80	0.64	0.58	0.77	0.60	0.67
Damages	0.08	0.14	0.07	0.09	0.14	0.12	0.11
Traffic, general, and miscellaneous	0.35	0.40	0.29	0.36	0.42	0.37	0.36
Total cost	$3.90	$3.80	$3.60	$3.82	$4.01	$3.37	$3.75
Revenue	3.40	3.64	3.91	4.32	4.22	3.86	3.90
Profit	−0.50	−0.24	0.31	0.50	0.21	0.49	.....

As shown by Table 7 the Barge Line has established a cost of operating towboats, barges, and terminals, which information is vitally necessary for prospective future operators of private lines. The average length of haul of the Mississippi Division is slightly less than 1 000 miles. Therefore, Table 7 gives very closely the cost per ton-mile of haul by reading mills instead of dollars for the costs as given.

The minimum, yet very profitable, rate charged by the Barge Line is 2 mills per ton-mile on export grain. The cost of loading and unloading is borne by the consignor. The rate on bauxite ore is about 2½ mills per ton-mile, which includes loading costs only.

In making comparisons between railroads and waterways, the difference in distance *via* rail or water should be considered. For the Mississippi Valley

System as a whole 1 mile of rail haul is equivalent to about 1½ miles of water haul. In Table 8 are given typical rail and river distances, together with corresponding rates.

TABLE 8.

New Orleans, La., to:	Distance, in Miles.		Cost per Ton.	
	Rail.	River.	Rail, fifth-class.	All-river.
Cairo, Ill.	554	969	$15.00	$3.90
St. Louis, Mo.	716	1 167	17.20	4.24
Chicago, Ill.	921	1 519	19.40	4.84
St. Paul, Minn.	1 330	1 850	24.20	5.40
Cincinnati, Ohio	836	1 468	18.80	4.75
Pittsburgh, Pa.	1 147	1 937	22.10	5.55

The all-river costs are estimated from the six years, 1923 to 1928, assumed as average revenue per ton between New Orleans and Cairo plus 1.7 mills per ton-mile of additional river distance to cover added cost of vessel operation. About 70% of the total river traffic consisted of grain, sugar, and bauxite ore, hence the river rates offer no basis of comparison with fifth-class rail rates, except to indicate how profitable fifth-class freight would be to water carriers.

It is quite evident that a privately owned line with fixed charges of taxes and interest could not survive as a common carrier under the operating costs and revenues allowed this Federal Barge Line. However, there are two items which give promise of substantial reduction, namely, wharf labor, now costing more than 90 cents, and fuel, 60 cents, per ton of freight handled. The type of equipment is steadily being improved and the effect of this on operating costs is marked. For instance, the cost of operating the Barge Line's tunnel-propeller towboats for 10 months in 1925 was 1.29 mills per ton-mile, whereas, that for two stern-wheel towboats was 2.56 mills.

While the profitable operation of common carriers by private capital is yet to be demonstrated, the same is not the case with respect to private or contract carriers. The private carrier usually will be a quantity producer, also, occasionally, a distributor of a more or less specialized product. The investment and operating cost of terminals and floating plant for quantity products will always be materially less than for the common carrier, which at all times must be prepared to handle a great variety of items of commerce in relatively small quantities. If such were not the case, many large corporations would have utilized the Federal Barge Line on the Mississippi River instead of developing their own private lines. Smaller corporations with occasional barge-load shipments will be a prolific source of business for the contract carrier.

At the present stage of the renaissance of inland waterway transportation too little consideration is apt to be given to the contract carrier. A towboat provides a very attractive and comfortable home for an entire family as

well as a means of livelihood. There are many such on the rivers to-day, and their number will increase rapidly as commerce develops. In fact, their existence in numbers might prove very embarrassing to the common carriers on account of competitive rate-cutting on port-to-port business.

Economic Advantage of Inland Waterway Transportation

The minimum direct benefit of waterway transportation to the shipping public has been fixed by the Interstate Commerce Commission for the Barge Line at 20% of the rail rate from port-to-port of the water haul. It is fair to assume that this will hold for the entire Mississippi Valley System.

The average rail rate of the United States is about 11 mills per ton-mile; hence, the minimum freight rate saving will be 2.2 mills per ton-mile of rail-haul or about 1.5 mills per ton-mile of water-haul. On the basis of 60 000 000 000 ton-miles of water-borne traffic by 1950, the total freight rate saving would amount to about $90 000 000 per annum.

Another very substantial economic advantage of waterway transportation is the saving in interest on the difference in capital cost of rail or water-transportation facilities now under discussion. The additional capital requirements for railroad construction as developed in this paper are premised upon an improvement in the efficiency of railroads amounting to about 50% between 1925 and 1950. Then there would be no doubt but that the railroads would earn 5¾% in excess of the stipulated fair rate of return, and hence this rate of interest on capital cost may be assumed.

As previously developed 60 000 000 000 ton-miles of waterway transportation facilities at 1 cent per ton-mile of capacity, would cost $600 000 000, whereas the equivalent railroad capacity of 40 000 000 000 ton-miles at 4.7 cents per ton-mile, would cost $1 880 000 000. The difference in favor of waterways is $1 280 000 000 and the interest charge saving at 5¾% amounts to $73 600 000 per annum.

It may be argued that this interest on saved capital cost may not be set up to the advantage of waterways as an economic saving, on the ground that it is immaterial to the investing public whether the capital is invested in railroads or elsewhere. This may be true so far as the owners of capital are concerned, but it is not true with regard to industry. The interest on capital invested in an industry, where the product can be furnished at the same or less cost by other methods without using the additional capital, is wasted so far as that industry or the users of its product are concerned.

Capital saved from investment in an industry where it is not needed remains available for investment where it is needed, or as part of a capital surplus tending to reduce the interest rates which are a tax on industry and on the economic welfare of the Nation.

Therefore, the writer presents as his answer to Question (*e*) that the minimum economic advantage of inland waterway transportation on the Mississippi Valley System by 1950 will be an annual freight-charge saving of $90 000 000 plus an interest-charge saving of about $73 600 000, or a total annual saving of about $160 000 000 based on a waterway freight movement of 60 000 000 000 ton-miles per annum.

Conclusions

The writer's conclusions, as developed in this paper, are as follows:

(*a*-1).—The annual freight transportation demand of the United States by 1950 will be 870 000 000 000 ton-miles, or 470 000 000 000 in excess of 1925.

(*a*-2).—Railroad renewals and increased operating efficiency may provide for an increase of 240 000 000 000 ton-miles.

(*a*-3).—Additional transportation facilities must be provided for about 230 000 000 ton-miles.

(*b*).—Additional railroad facilities for 230 000 000 ton-miles will cost about $11 000 000 000, or 4.7 cents per ton-mile of practical ton-mile capacity.

(*c*-1).—Additional freight demand of the Mississippi Valley by 1950 will be 120 000 000 000 ton-miles, 60 000 000 000 of which will require additional transportation facilities.

(*c*-2).—The Mississippi Valley Inland Waterway System, when completed, will provide an improved right of way sufficient to accommodate more than 200 000 000 000 ton-miles of freight traffic, if it were available.

(*c*-3).—The growth of waterway traffic on the Mississippi System between 1919 and 1928 has been equivalent to more than 15% annual increase. If this is continued at 10% annual increase with new completed waterways added, it will produce 60 000 000 000 ton-miles per annum by 1950, or the equivalent of 40 000 000 000 ton-miles of railroad traffic.

(*d*).—The cost of completing present approved project waterways and providing transportation facilities thereon at 1 cent per ton-mile of traffic expectancy will be about $600 000 000 for 60 000 000 000 ton-miles capacity of floating plant and necessary terminals.

(*e*).—The economic advantage of completing and utilizing the Mississippi Valley Inland Waterway System by 1950 will amount to a minimum of $160 000 000 per annum.

RELATION BETWEEN RAIL AND WATERWAY TRANSPORTATION

By E. A. Hadley,* M. Am. Soc. C. E.

Synopsis

The proposition to improve and maintain inland waterways at Government expense, particularly on the larger rivers, leads to the consideration of the economic aspects of such an undertaking which may result in a reduction of earnings to other transportation agencies through Government subsidized competition.

The writer endeavors to set forth the situation in such manner as to point out the inequalities which he believes would result from expenditure of the vast amounts of Government funds which would be required to provide and maintain adequate navigation channels on the principal American rivers to be used in competition with the railroads.

The paper traces the development of transportation in the United States and sets forth the present relation of the railroads to the Government through its regulation of rates and profits from operations.

The result of Government operation of barge lines in the Mississippi-Warrior Service is commented upon and comparison is made of the cost of construction of railroads in place of the proposed improvement of the St. Lawrence Waterway.

The paper closes with an appeal for consideration of the economic phases of expenditure of Government funds to foster private enterprise when such funds are secured largely from taxation of the whole people.

Although this subject is sufficiently broad to include transportation on the Great Lakes as well as coastwise traffic where interchange is had with the railroads, the treatment will be confined largely to the relation between the railroads and the inland waterways, as represented by the larger rivers.

Early Development

In the beginning of the Nation's history waterways were the natural highways. With the invention of the steam engine and its application to boats, their use for transportation purposes became almost universal. The Civil War broke in twain these lines of communication between the North and South and that infant industry, the railroads, ever pushing westward, attracted and took the business, offering facilities cheaper, more convenient, and more expeditious than the rivers.

It was transportation, particularly rail transportation, that speeded up agricultural development. Water transportation, in the early days, made collection and distribution possible, but the great West would have remained unsettled had not steam been found applicable to the purpose of transportation.

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In the "good old days" of steamboat transportation the farmer's wheat came from such fields of the Northwestern States as were adjacent to the water routes and was handled down the river by steamer to the great markets of the time—St. Louis, Mo., and New Orleans, La. Examination shows that the rates were much in excess of any current charges.

To permit shipment by boat the farmer was obliged to pack his grain in 2-bushel sacks costing approximately 20 cents each or, say, 10 cents per bushel. Grain is now hauled in bulk by the railroads from the "Twin Cities" to Chicago, Ill. (425 miles) for 8.1 cents per bushel, or less than the cost for sacking alone prior to the Civil War.

To meet the railroad competition it was necessary for the steamboats to adopt more efficient methods and to provide better facilities. Special grain barges came into existence and did away with the necessity of sacking the grain. For many years following the "period of reconstruction" there was probably the best co-ordination of rail and water transportation that the United States has ever experienced.

The necessity for transfer between barges and railroad cars involved expense and necessity for extensive elevator facilities at both the north and south ends of water routes. As the sources of grain extended back into the interior and the haul by rail increased into the Northern elevators, it was found more expedient and economical to carry the grain the entire distance by rail to the exclusion of the steamboats and barges.

Status of American Railroads

The United States, with less than 8% of the world's area and less than 6% of the world's population, has more than 85% of the world's railroad mileage. It is generally conceded that American railroads give the best service at the lowest cost; that no other transportation medium can handle the enormous crops or the immense amount of raw materials, as their lines reach to all producing centers and into all markets of the country, both great and small.

The rivers do not produce any new traffic. What they do haul is taken away from the railroads, which, taken as a whole, are now equipped to handle a greater amount than that represented by their present traffic plus that handled by the barge lines. It is questionable whether inland water transportation on the rivers can be revived and improved to such an extent as to enable it to compete successfully with the railroads of to-day, which are increasing in efficiency from year to year and rendering it correspondingly more difficult for other methods to compete with them.

Limitation of Rates and Profits

The statement often made, that the development of the inland waterways and their operation will lower freight rates, is contrary to the facts. River rates are now placed at a percentage of the railroad rates. Therefore, no incentive exists for the railroads to lower their rates, as the river rates would then be correspondingly lowered and the same percentage of differential would continue to exist.

The Transportation Act of 1920 provides that the railroads shall be permitted to earn a reasonable percentage on the value of their property devoted to transportation purposes. Obviously, any other agency tending to take revenue away from the railroads, whether operated by private capital or subsidized by the Government itself, is not working toward a lowering of rates but, on the contrary, will have a tendency to increase the rates in order to provide gross earnings necessary for the fair return contemplated under the law.

The Government restricts the profits of the railways as it does not those of any other large industry. It subsidizes competition with them as it does not with any other industry, by spending billions of dollars in improving highways and waterways upon which other carriers operate without paying adequately or submitting to such regulation of their service and rates as do the railroads.

Competition with Subsidized Waterways

The territory known as the Mississippi Basin is the chief wealth-producing section of the United States. This area contains 54% of the nation's population and 66% of its rural population. It covers 64% of the total area and produces 70% of the total agricultural products, 52% of the total manufactured products and 68% of the total exportable products. It is in this territory that the Government is carrying forward its "experiment", under the direction of the Inland Waterways Corporation, to demonstrate the supposed economies of a water-transportation system by improvement of the navigable rivers and operation of barge lines thereon.

It is the privilege of the American people to undertake the development of any transportation agency they desire. On the other hand it is contrary to American principles to expend the money of all the people for the development of an enterprise which, due to its location, can be helpful to but a small portion of the people and even then only by doing great injury to another branch of the same industry upon which all of the people must depend.

If river transportation can be produced at a substantially lower cost to the public than railroad transportation, the public would be justified in encouraging such development and using such a method of transportation in place of railroads. As the railroads cannot be discarded they must be supported. Any arrangement entered into by the Government whereby the public pays more for transportation and the individual shipper less is not economically sound.

Real Cost of Transportation

It has been stated that:*

"Our Great Lakes carry more freight and at a cheaper rate per ton-mile than any other inland waterway system of the world. The annual savings in transportation costs on the lakes are also greater than the entire cost of all improvements that have been made."

Nothing approaching this situation, however, can be said of river transportation as now sponsored by the Federal Government.

* In a recent address by Edgar Jadwin, Major-General (*Retired*), U. S. Army, M. Am. Soc. C. E., before a joint meeting of the Society of Terminal Engineers and the New York Post of the Society of American Military Engineers.

In considering the real cost of any form of transportation it is necessary to take into consideration all factors entering into that service, not only those which are positive in character but also those which may be negative, this latter being best exemplified by the item of taxation. The railroads of the United States pay in yearly taxes almost $400 000 000; the Government-operated barge lines pay nothing. The railroads furnish and maintain at their own cost their right of way, roadway structures, and signal systems. All these items are furnished to the barge lines by other departments of the Government without charge.

If all the costs incurred by the Government through its various departments to maintain navigation on rivers were assembled and charged against the cost of operation of the barge lines, the cost per ton of freight transported would be so enormous that its realization would doubtless discourage further development along these lines. Looking at the matter any way, if the railroads were relieved of taxes and the cost of maintenance of roadway and if their terminals were provided at the expense of the large cities, as is now done for the barge line service, doubtless their rates could be reduced far below those now charged by the barge lines.

The rates now assessed for water transportation are certainly not all that is paid through some source for the service which is rendered. The railroads not only lose the traffic handled by the river, but see a part of their annual tax payments go toward paying the cost of supporting their Government-operated competitor.

The real question at issue regarding the proposed further development of inland waterways is whether or not the cost of transportation to the public as a whole will be decreased or whether only individual shippers would benefit by this service, the deficits through operation and the cost of the improvement work to be paid from taxes or buried in the records of other departments of the Government. If the benefit is to accrue to individual shippers only, then it is unfair to the rest of the people.

Results from Government Barge Line

Since 1920 the Mississippi-Warrior Barge Line, owned and operated by the Government, has carried about 7 775 000 tons of freight at an average annual loss of approximately $440 000, based on its own system of bookkeeping, covering transportation expenses only. The public deserves to have the accounts stated in such manner that it may find out whether the Barge Line shippers are paying the full cost of transporting their shipments or whether they are being subsidized, and to what extent, by the Federal Government at the expense of the people as a whole.

At the time the Inland Waterways Corporation was established the people were told that the sole purpose was to demonstrate that river transportation was a sound investment for private capital. Until this enterprise can be made to show a profit, taking into account capital investment, taxes, and maintenance, and all other items of expense now subsidized by the Government, there can be no hope of interesting private capital in its operation. Another fact to be noted, especially in connection with the present proposals to extend

barge service into the Upper Mississippi and its tributaries, is that these waterways are open for navigation only seven or eight months of the year.

Direct expenditures on these natural waterways, including tributaries, have already exceeded $600 000 000. It cannot be considered sound public policy to reduce railroad earnings, impair railroad credit, and render railroad service inadequate in order that a field may be provided for water services, which at best can, and should be, only supplementary to the railroads.

Substituting Railroads for Canals

The reason advanced for the development of the St. Lawrence waterway is cheaper transportation costs to reach foreign markets, particularly for American wheat. Available American farm lands are approaching maximum production and the population is increasing. It is possible that by the time the waterway could be made ready for service there would be no grain to export. If there were a surplus there is no assurance that it would be located sufficiently close to the Great Lakes territory to enable it to use the St. Lawrence waterway.

It has been estimated* that three double-track, fully equipped railroads could be built from Chicago to Boston, Mass., at a cost of $260 000 000 each, the total cost of the three railroads being about the estimated cost of the St. Lawrence waterway; and that each of these railroads, operating throughout the year to its theoretical maximum capacity, could handle eight times as much freight as the proposed waterway. In other words, the three railways would cost only slightly more than the proposed waterway and combined could carry about twenty-four times as much freight.

The New York State Barge Canal has cost more than $270 000 000. Prior to its construction it was estimated that it would handle 20 000 000 tons of freight per year, but in its best year (1928) it handled a little more than 3 000 000 tons. Any one of the railroads operating between Buffalo and New York could have handled this entire traffic without disturbance of its normal business. The canal costs the people of New York State nearly $11 000 000 per year so that the taxpayers would have saved approximately $4 500 000 if all the freight had been handled by the railroads with the State paying the charges, and the shippers would have saved about $3 000 000.

Taxes as Affecting Rates

Railroad transportation rates, however, are declining while taxes are increasing. Rates have been lowered until in 1928 they produced an income of $850 000 000 less than if the rates in effect in 1921 had been applicable. The total earnings of the Class I railroads in the first quarter of the calendar year 1929 were about $8 000 000 greater than in the first quarter of 1926.

Their taxes, however, were more than $7 500 000 greater, the net result being that the public took back in increased taxes almost all that it paid in increased earnings for the handling of a larger freight traffic. The net operating income earned represented an increase of about $37 000 000 over the first

* "Economic Features of the Proposed St. Lawrence Waterway," Address by Dr. H. G. Moulton, Pres., Brookings Inst., Washington, D. C., before the Traffic Club of Chicago, on March 21, 1929.

quarter of 1926, but it was entirely due to reduction in operating expenses that was secured in spite of advances in wages.

In an address* in Washington, President Coolidge issued a warning to the American people regarding the menace to National prosperity that is presented by the enormous increases in expenditures made by the Government and the resulting increases in taxes. He stated that the cost of State and local governments increased from $3 900 000 000 in 1921 to $7 931 000 000 in 1927 and that such a heavy drain on the earnings of the people is the greatest menace to the continuance of prosperity.

The National Industrial Conference Board has emphasized† that the Nation's total tax bill in 1923, only five years after the World War, was $7 234 000 000, while in 1928, ten years following the close of the war, it was $9 169 000 000, an increase within the five-year period of 25 per cent. Taxes are increasing faster in proportion than either the population or the National income. In 1923 they were less than $65.00 per capita; in 1927, $76.50 per capita; and in 1928 still more. In 1913 taxes were only 6.4% of the National income. In 1923 they were 10%; in 1927, 12%; and in 1928, 12½ per cent.

Success without Subsidy?

The railroads as a whole are not opposed to river transportation if it can be successfully conducted without being subsidized. They have co-operated in a constructive manner in the provision of port terminal facilities and in the application of joint rates. They should not be compelled, however, to meet a competition that cannot stand alone. Further expenditures by the Government to extend river transportation will certainly have to come out of revenues received from taxes, which are already burdensome enough.

The present is an era of great and rapid change—of an economic nature—perhaps the greatest the country has even experienced. It is not confined to any particular section but is nation-wide and varied in character. Many of these changes are occuring faster than corrective formulas can be devised and this warrants unusual and careful consideration of all measures designed for relief.

The people of the United States are optimists, due largely to the fact that for more than 150 years they have had almost continuous growth and properity and have developed a sense of confidence and faith that, as a people, they can overcome any critical situation.

With growth in size and strength the Nation must use a proportionately greater effort to comprehend the enlarged scope of economic effects, being not too hasty in applying untried or ill-considered methods of either assistance or control. It must not lose sight of the fact that in the creation and distribution of wealth the public must bear the financial burden caused by every error made in the application of economic theories. The welfare of the whole people must be safeguarded by those in charge of public affairs.

* Address before the Sixteenth Regular Meeting of the Business Organization of the Government, at Memorial Continental Hall, Washington, D. C., on January 23, 1929.

† "Cost of Government in the United States, 1926–1927", pub. in 1928, by the National Industrial Conference Board, Inc., pp. 59 and 82.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

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IRRIGATION HYDRAULICS*

PROGRESS REPORT OF THE SPECIAL COMMITTEE

To the Board of Direction,
American Society of Civil Engineers.

Gentlemen.—The Committee held two meetings in 1929—one at San Francisco, Calif., May 10 and 11, and the other at Eugene, Ore., December 19 to 21.

After the May meeting the Committee was taken for an inspection trip to the Salt Springs Dam on Mokelumne River through the courtesy of the Pacific Gas and Electric Company. The Lafayette Dam, recently failed, and the Pardee Dam, of the East Bay Municipal Utilities District, were also visited on the trip.

In order to avoid any overlapping of the work of this Committee and the Committees of the Irrigation Division, the following resolution was passed at the May meeting:

"*Be it Resolved* that it be the policy of this Committee to continue its efforts to co-operate fully with the Irrigation Division: *First* by maintaining, if possible, a member of this Committee on the Executive Committee of the Division, as a permanent point of contact such as now exists through Mr. Scobey; *Second* that future subjects for research by this Committee be discussed with the Executive Committee before their adoption; *Third* that any suggestions made to this Committee by the Executive Committee of the Division be carefully considered."

After the December meeting an examination of the Leaburg Hydro-Electric Development of the City of Eugene, Ore., on the McKenzie River, was made through the courtesy of the Eugene Water Board. This development has several interesting features under study by the Committee, which prompted the selection of Eugene for the place of meeting. Among them are:

(1) Baffles on the apron of the diversion dam to prevent scour. (Subject VII.)
(2) A system of pressure pipes for determining uplift. (Subject III.)

* Presented at the Annual Meeting, January 15, 1930.

(3) Two modern fishways of liberal design and an oscillating fish screen to prevent fish from entering the power canal. (Subject XI.)

(4) A battery of seven siphon spillways having a total capacity of 3 500 sec-ft. (Subject IV.)

On July 25, President Marston appointed Julian Hinds, M. Am. Soc. C. E., a member of this Committee. Mr. Hinds was formerly a member, but resigned October 25, 1928, as he was out of the United States and unable to attend the Committee meetings. Since then, however, he has returned to the United States. All members are very happy to have him with the Committee again.

The list of subjects selected for study and research, the Sub-Committee, and co-operating members in charge, are as follows:

I.—Evaporation Losses from Reservoirs.—Sub-Committee: F. C. Scobey, R. L. Parshall, A. L. Sonderegger, and Ivan E. Houk.

I(A).—Evaporation from Soils.—Sub-Committee: Franklin Thomas, A. L. Sonderegger, R. L. Parshall, and Ivan E. Houk; co-operating member, H. F. Blaney, Assoc. M. Am. Soc. C. E.

II.—Losses in Canal Conversions.—Sub-Committee: J. L. Savage, J. C. Stevens, F. C. Scobey, and R. A. Monroe.

III.—Water Movement and Pressure Under Dams.—Sub-Committee: J. L. Savage, R. A. Monroe, and B. A. Etcheverry; co-operating member, R. D. Hubbard, Engineer, U. S. Bureau of Reclamation, Denver, Colo.

IV.—Losses in Siphon Spillways.—Sub-Committee: F. C. Scobey, Franklin Thomas, and A. L. Sonderegger.

V.—The Silt Problem.—Sub-Committee: Franklin Thomas, B. A. Etcheverry, and Ivan E. Houk; co-operating member, E. S. Lindley, M. Am. Soc. C. E.

VII.—Scouring Below Dams.—Sub-Committee: R. A. Monroe and B. A. Etcheverry; co-operating members: I. C. Steele, P. O. Crawford, and H. E. Gruner, Members, Am. Soc. C. E., and W. H. Nalder, M. Am. Soc. C. E.

VIII.—Irrigation Deliveries.—Sub-Committee: R. L. Parshall, J. C. Stevens, and Ivan E. Houk; co-operating members, E. S. Lindley and H. W. King, Members, Am. Soc. C. E.

IX.—Lateral Flow Spillways.—Sub-Committee: J. L. Savage, R. A. Monroe, and B. A. Etcheverry.

XI.—Fishways and Fish Screens.—Sub-Committee: R. A. Monroe, J. C. Stevens; co-operating member, Shirley Baker, M. Am. Soc. C. E.

Nomenclature.—Sub-Committee: B. A. Etcheverry, J. C. Stevens, and F. C. Scobey.

The policy of the Committee has been to stimulate research by public and private agencies having special facilities and opportunities and to make available in published form much valuable data that might otherwise never become available for general use.

During the past year the following papers have appeared as a tangible result of the Committee's work:*

* For a complete list of papers prepared in co-operation with the Committee, see *Proceedings*, Am. Soc. C. E., March, 1928, Society Affairs, p. 173; *Loc. cit.*, March, 1929, Society Affairs, p. 95.

"Use of Water on Federal Irrigation Projects,"* by E. B. Debler, M. Am. Soc. C. E.

"Experiments to Determine Rate of Evaporation from Saturated Soils and River-Bed Sands,"† by Ralph L. Parshall, Assoc. M. Am. Soc. C. E.

"Water Supply from Rainfall on Valley Floors,"‡ by A. L. Sonderegger, M. Am. Soc. C. E.

"Sand Problems at Franklin Canal Intake, Rio Grande Project,"§ by Ivan E. Houk, M. Am. Soc. C. E.

"Evaporation as a Function of Insolation,"‖ by Burt Richardson, Physicist, Norman Bridge Laboratory, Pasadena, Calif.

Status of Investigations

I.—Evaporation Losses from Reservoirs.—The long contemplated evaporation study at East Park Reservoir on the Orland Project, California, was again frustrated for lack of rainfall. While the Stony Gorge Dam has been completed, it was not possible to hold the East Park Reservoir water in the spring of 1929 as had been anticipated. Instead, stored water in both reservoirs was pooled early in the season.

The paper on "Evaporation as a Function of Insolation," by Burt Richardson, Physicist at Norman Bridge Laboratory, Pasadena, Calif., has been accepted for publication in *Proceedings*.

The observations at Fort Collins, Colo., on an 85-ft. copper-lined evaporation tank have been discontinued. The results of two years' observations, however, are being prepared for publication by Carl Rohwer, Assoc. M. Am. Soc. C. E.

There has been considerable confusion owing to the variety of sizes and shapes of evaporation pans that have been used in the past. The Committee is making a study of the various types with a view to recommending the adoption of one as a standard. As a beginning Mr. Rohwer has in preparation a paper in which the various types now in use will be fully described and their advantages and disadvantages pointed out.

I(A).—Evaporation from Soils.—Mr. Houk is making an analysis of the data secured by the Rio Grande Conservancy District on evaporation from soils and salt grass cover and also on evaporation from a free water surface. These data will be assembled in the form of a paper and presented through the Committee.¶

II.—Canal Conversions.—Mr. Parshall has made some experiments on the head lost in simple expanding sections at the Bellvue Laboratory near Fort Collins, Colo. There appears to be an inherent eddy loss when velocities are reduced. The Committee is securing a mathematical analysis of this, the results of which will be tested by actual experiments.

III.—Water Movement and Pressure Under Dams.—A few laboratory experiments were made at the California Institute of Technology by Mr.

* *Proceedings*, Am. Soc. C. E., March, 1929, Papers and Discussions, p. 751.
† *Loc. cit.*, April, 1929, p. 843.
‡ *Loc. cit.*, May, 1929, p. 1139.
§ *Western Construction News*, November 25, 1928.
‖ Accepted for publication in *Proceedings*, Am. Soc. C. E.
¶ *Proceedings*, Am. Soc. C. E., March, 1929, Society Affairs, p. 96.

J. E. Skafte, a graduate student, under the direction of Franklin Thomas, M. Am. Soc. C. E., on the permeability of construction joints in concrete. The results secured were comparable with those obtained at the Bull Run Dam under the direction of D. C. Henny, M. Am. Soc. C. E.* These experiments showed that with the size of joints obtainable in laboratory experiments good adhesions were secured with the most ordinary care and that generally little or no pressure could be transmitted through the joints. In some of the Skafte experiments the first concrete was oiled before the second was placed, and even under such circumstances but very little pressure was transmitted.

Observations of uplift are being continued at the American Falls Dam, Idaho. Pipes for measuring uplift at horizontal joints within the concrete have been installed at the Gibson Dam, Montana, and are planned for the Owyhee Dam, Oregon.

The Leaburg Dam, Oregon, just completed, has pipes for determining uplift pressures under the spillway base. The results of all these observations will be presented in due time.

IV.—Siphon Spillways.—Experiments on a model of the siphon spillway on Johnson Creek, Kittitas Division, Yakima Project, were made in April, 1929, by O. G. Patch, Engineer, U. S. Bureau of Reclamation. Moving pictures of the siphon action were taken and these films, with the results of the tests, have been made available for study by the Committee, through the courtesy of the officials of the U. S. Bureau of Reclamation.

At the forebay of the Leaburg Hydro-Electric Development just completed by the City of Eugene, is a battery of seven siphon spillways, some of which will be almost constantly in operation. Piezometer tubes have been installed in each size at pertinent points throughout their lengths. A comprehensive set of experiments is contemplated in the near future.

The Committee is in receipt of a thesis by Messrs. Gunner Gramatky and Kenneth Robinson, graduate students at the California Institute of Technology, giving the results of laboratory experiments on a model siphon. The results are expressed as coefficients of discharge instead of in terms of friction, curve, and expansion losses.

Siphon losses are merely those of friction, curvature, and expansions in a pipe line, and should be computed as such. The discharge coefficient of siphons heretofore quite generally used varies over a wide range depending on the head, the length, expansion, number of curves, etc., in the siphon.

A recomputation by Mr. Scobey of the losses given by Scimeni† to segregate those due to friction, curvature, and expansions prove the truth of the foregoing statement.

V.—Silt.—The California Débris Commission has supplied the Committee with some profiles of stream beds above débris dams. A profile of an 11-mile stretch above a débris dam 20 ft. high on Bear Creek, near Colfax, Calif., showed that the débris fill was steeper than the original stream bed. For a fill of 20 ft. at the dam, the depth 5 miles up stream was 50 ft. and 11 miles

* *Proceedings*, Am. Soc. C. E., March, 1929, Society Affairs, p. 96.

† "Sul rendimento dei sifoni autolivellatori," by E. Scimeni, *Electrotechnica*, May 5, 1928, p. 2.

up stream, 100 ft. Profiles for the original stream bed and those of 1878, 1890, and 1927, are shown. There is a question as to how much effect the dam itself has had in forming the profile.

Mr. Parshall has done considerable work in perfecting an automatic silt-sampling device to be used in connection with the "Parshall Measuring Flume,"* which, at regular intervals, will collect samples of silts carried as bottom load in irrigation canals.

VII.—Scouring Below Dams.—Mr. Houk has prepared a paper entitled, "Scour Below Reclamation Bureau Dams," covering in a concise manner the extent of the scour and the control measures exercised at the various Bureau of Reclamation structures where erosion has taken place. Dams treated in the paper, thus far, are the Lower Yellowstone Dam, on the Lower Yellowstone Project; Vandalia and Dodson Dams, on the Milk River Project; Willwood Dam, on the Shoshone Project; and Jackson Lake Dam, on the Minidoka Project. Other dams to be treated are the Laguna Dam, on the Yuma Project; American Falls Dam, on the Minidoka Project; Granite Reef Dam, on the Salt River Project; Leesburg Dam, on the Rio Grande Project; and the Boise Diversion Dam, on the Boise Project.

Topographic surveys have been made below the Stony Gorge Dam on the Orland Project and below the Gerber Dam on the Klamath Project, so that any erosion which may occur when the spillways at these structures are brought into operation, can be accurately measured in the future. Topographic surveys have also been made below the needle-valve outlets at the Arrowrock Dam on the Boise Project and below the Tieton Dam on the Yakima Project, so that data on erosion at these structures will be available at later dates.

Baffles have been constructed on the apron of the Leaburg Diversion Dam on the McKenzie River. The topography of the river gravels below the dam has been taken so that the effect of these baffles can be determined. The dam is now in service, but only in flood periods can data on scour be secured.

VIII.—Irrigation Deliveries.—The Committee has felt that the name, "Improved Venturi Flume" is a misnomer, and steps have been taken to enlist the co-operation of certain other organizations in adopting a new name for this device, with the idea of giving credit to Mr. Parshall who is most responsible for its successful development. In addition to this Committee, the following have expressed themselves as agreeable to the adoption of a more fitting name:

> Executive Committee, Irrigation Division, American Society of Civil Engineers.
>
> S. H. McCrory, M. Am. Soc. C. E., Chief, Division of Agricultural Engineering (of which Mr. Parshall is a member), Bureau of Public Roads, U. S. Department of Agriculture.
>
> W. W. McLaughlin, Associate Chief, Division of Agricultural Engineering, Bureau of Public Roads, U. S. Department of Agriculture.
>
> C. L. Lory, President, Colorado Agricultural College, working in co-operation with the Federal Division of Agricultural Engineering, through Mr. Parshall.

* Formerly called "The Improved Venturi Flume," *Bulletin 336*, March, 1928, Colorado Experiment Station, Colorado Agri. Coll., Fort Collins, Colo.

The Committee at its December meeting unanimously adopted the term, "Parshall Measuring Flume," and recommends its general use in place of, "Improved Venturi Flume."

The work of installing and testing Parshall Measuring Flumes in sizes from 6 in. to 40 ft. has been continued throughout Colorado and elsewhere. Many corroborative tests have been secured, which confirm this as a practicable and inexpensive measuring device.

Experiments are being made on an adjustable tube meter for irrigation work at the Fort Collins Laboratories. This device is intended to meet conditions where there is practically no head available for measuring devices. So far the experiments are encouraging. Field tests will next be undertaken.

H. W. King, M. Am. Soc. C. E., Professor of Hydraulic Engineering, University of Michigan, has agreed to undertake some laboratory experiments on other devices that depend on critical depths for measuring flows.

Attention is called to the "stick method"* of measuring water developed by Messrs. Clawson and Pierce on the Salt River Project, in Arizona.

IX.—Lateral Flow Spillway.—The proposed experiments† on the lateral flow spillway at Tieton Dam, Yakima Project, Washington, could not be made this year due to limited reservoir storage and lack of personnel for outlining and conducting the work. It is planned to make the experiments during the spring flood next year if storage and personnel conditions are favorable.

XI.—Fishways and Fish Screens.—The Committee is gathering data on existing structures that appear to have merit. It is co-operating with a committee of the National Electric Light Association on the same subject. The problem of caring for fish at dams is believed to be one that admits of a satisfactory solution. All that is needed is a spirit of earnest co-operation on the part of all parties concerned.

Nomenclature.—The preparation of a glossary of irrigation terms and symbols for irrigation hydraulics has reached an advanced state. It is expected that the Sub-Committee's report will be completed shortly and the results submitted for publication.

Respectfully submitted,

D. C. Henny, *Chairman,*
J. C. Stevens, *Secretary,*
B. A. Etcheverry,
J. L. Savage,
F. C. Scobey,
Franklin Thomas,
Ralph L. Parshall,
Ivan E. Houk,
A. L. Sonderegger,
R. A. Monroe,
Julian Hinds.

December 4, 1929.

* "Hydraulic Measuring Stick," by J. B. Lippincott, M. Am. Soc. C. E., *Western Construction News,* August 25, 1929, p. 424.

† *Proceedings,* Am. Soc. C. E., March, 1929, Society Affairs, p. 97.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

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INTERSTATE WATER MATTERS

PROGRESS REPORT OF THE COMMITTEE OF THE IRRIGATION DIVISION

The last report of the Committee was submitted at the meeting of the Irrigation Division in Denver, Colo., on July 14, 1927.* No meetings of the Committee have been held since that time.

However, since July, 1927, many important problems concerning interstate streams have arisen. Some of these problems have been settled by Court decision and others by compact, but the solution of the majority of them is still pending. Other important problems are in the offing. The West probably still occupies the center of the arena of interstate water matters, due to the magnitude of the current problems, but during the last two and one-half years several important interstate water controversies have arisen in the East.

Only three interstate water controversies have been decided to date by the Supreme Court of the United States, *viz.*: Wyoming *vs.* Colorado; Kansas *vs.* Colorado; and the controversy over diversions by the City of Chicago, Ill., of Lake Michigan water. The first two cases were between States in which the principle of appropriation was in effect. That principle was recognized by the Court, in the Colorado-Wyoming Case. The last, the Chicago Diversion Case, was a controversy between riparian right States, and it was hoped by the States in which that principle applies, that the Court in its decision would establish a precedent by defining the relative rights of riparian owners along a stream system. Such was not the case, the Court basing its decision on the power of the National Government to regulate commerce between States, and more specifically on an act imposing upon the Secretary of War the obligation of removing obstructions to navigation. Two suits have been filed recently, *viz.*: New Jersey *vs.* New York and Connecticut *vs.* Massachusetts, in the Supreme Court of the United States, which should result in a decision establishing a precedent to be followed in riparian right States. The outcome of these two suits will be awaited with a great deal of interest.

Several important international questions over waters are in progress of solution. These are discussed in more detail later.

* *Proceedings*, Am. Soc. C. E., March, 1928, Society Affairs, p. 120.

There is a growing consciousness among the States that have interstate streams, or of which water is an important resource, that the question of Federal *vs.* State control of unnavigable unappropriated waters should be definitely determined.

It is probably true that the principle that States have full control of their waters so long as they are not navigable, is well established, due to the intricate systems of administration and rules of appropriation that States have built up to administer and distribute those waters; the repeated recognition of those systems by decisions of Federal Courts and Executive orders; and the implied recognition of the States' ownership of such resources by various acts of Congress. Yet there are still some attorneys who maintain that the Federal Government has control of interstate streams. The question should be settled. Much discussion has been had on the subject during the last two and one-half years.

The subject is considered of major importance by the Association of Western State Engineers. Since the creation of the Federal Power Commission, New York State has been fighting for the right to control her own water power resources and she has been in a large measure successful. Maine has done likewise, and not only controls her water power resources, but has a law which prohibits the export of power. The law to date has been effective. The States of the South are fighting to control their own water power resources as against Federal control. In a decision by the Supreme Court of the United States over a power case in Wisconsin, the Court pointed out the sovereignty of a State over navigable streams subject to the higher authority of the Federal Government. A certain power company in Wisconsin had failed to comply properly with a law passed in 1925 requiring all owners of power dams to acquire a permit from the State to continue operation, etc. The dam in question was built in 1878 and riparian ownership was claimed. The United States Supreme Court upheld the State law.

It is interesting to note that the Federal Power Commission in its annual report for 1928 advocated legislation in States providing for a joint commission to regulate the transmission of power between the States. If the power were sold direct to consumers the final jurisdiction was to rest with the States, but if the power from one State were sold to distributing companies in another State, the State decisions were to be subject to Federal Court review since such sales would come under the head of interstate commerce.

On the other hand the exigencies of some of the major problems before the country have led some leading engineers to believe that the Federal Government should have control of interstate waters. As an example of this, American Engineering Council's Committee to consider Mississippi Flood Control, composed of John R. Freeman, Past-President, Am. Soc. C. E., and Gardner S. Williams, Baxter L. Brown, and Arthur E. Morgan, Members, Am. Soc. C. E., at the meeting in January, 1928, made the following statement:

"It is the opinion of this Committee that the authority of the General Government to deal with such questions as are involved in the Mississippi River problem should no longer hang upon such slender threads as the general

welfare clause or the regulation of commerce clause of the Constitution, but that the Constitution of these United States should be amended to confer upon the General Government the authority to control and administer the national waters and to assess damages and allocate benefits and costs in connection therewith.

"It is our further opinion that only by the procedure which such an amendment, followed by the passage of a Federal Water Control law, would make possible, can an equitable or justifiable distribution or allocation of the costs of river improvement and flood protection be assumed."

The same view was expressed by Mr. Morgan at the Assembly of American Engineering Council held in Washington, D. C., on January 14 and 15, 1929, and it is understood that steps are being taken, looking to the introduction of the necessary legislation to bring about the proposed amendment.

It is believed from the discussion that has taken place recently in the West that such a procedure as that stated would not meet with favor among the Western States. The Western States prefer to settle their own differences as to interstate waters by compact, or even by Court action when necessary, rather than to submit the administration of those waters to the remote control of a Federal Bureau which would have no knowledge of the complex, intricate problems of a local nature involved in their administration.

It is believed further that the Western States are opposed to submitting control of the upper tributaries of the Mississippi which rise in those States to any Federal commission—the Mississippi River Commission or otherwise. Such control is gradually being sought on the plea of the necessity of regulating the flow of those tributaries as a part of the Mississippi Flood control plan. The following statement by the Engineering Council Committee cited is worthy of note:

"Storage reservoirs on the remote head-waters of tributary streams have too limited an effect upon the floods of the Mississippi River to justify their inclusion in the flood protection program for that river."

This discussion is given to indicate the importance and complexity of the problem, and the desirability of full discussion by all interested parties to the end that a constructive program might be evolved for its solution. It is believed now is an opportunte time to bring the problem to the front. The National Executive is an engineer, and it is understood that he is in favor of as little Federal control of National resources as is possible. The Federal Land Commission recently appointed by him to consider the desirability of turning over to the States, the Government land within those States, and allied matters, should properly consider the all important question of the control of interstate streams and unnavigable unappropriated waters.

The following gives a brief discussion of some of the most important interstate problems that were in evidence during 1928 and 1929.

Very truly yours,

M. C. HINDERLIDER, *Chairman,*
Committee on Interstate Water Matters.

January 11, 1930.

St. Lawrence River.

(Canada and United States)

Negotiations have been under way since 1921 between Canada and the United States in an endeavor to reach an understanding concerning the development of the St. Lawrence River as a waterway. In 1921, Messrs. Bowden and Wooten made a joint report to the International Joint Commission concerning the proposed development. In 1924, the United States Government appointed a National Committee called the St. Lawrence Commission of the United States, headed by President Hoover, then Secretary of Commerce. Canada appointed a National Advisory Committee to meet with the United States Committee. These two Committees met and appointed a board of engineers composed of members from the two countries to review the Bowden-Wooten report. The Engineering Board made its report in November, 1926.

The plan of development as finally recommended provides for the construction of a navigation channel 25 ft. deep in the 183-mile section of the river between Lake Ontario and Montreal, Que., Canada, together with nine locks, twenty-five miles of canal, an initial power development of 2 700 000 h.p., and an ultimate development of 5 000 000 h.p.

Some discussion was carried on between the two countries during 1927 and 1928. It is reported that the views of both countries are close together as regards the major features of the project. Canada desires a 27-ft. channel, credit for certain improvements completed on each side of Montreal, and for the Welland Canal, and does not want to develop power beyond her ability to absorb it, as she is opposed to the export of power. It is reported that the United States is of the opinion that Canada should receive credit for only those improvements which will be embodied in the final plan of development, and while the United States Government concedes that all the power developed in Canada and one-half of that developed on the border should go to Canada, yet it believes full development of the potential power possibilities should be made in one stage.

Difficulties arose in Canada over the question of ownership and control of the power that was to be developed by the St. Lawrence Project. The controversy was between the Dominion Government and the Provincial Governments of Ontario and Quebec. The question was referred to the Canadian Supreme Court, but the decision rendered by the Court appears to have been not conclusive. This condition has precluded the possibility of further negotiations between the two Governments pending some sort of agreement between the Dominion Government and the Provinces.

It is reported that Premier MacKenzie King announced in the early part of 1929 that at the close of the session of Parliament a conference would be called between representatives of the Dominion and the Provinces of Ontario and Quebec in an attempt to arrive at an agreement in order that negotiations might be resumed with the United States. It was further stated that no treaty would be finally negotiated until Parliament had ratified each clause.

The New York State Government has recommended the development of power on the St. Lawrence at State expense, the distribution to be made by private interests.

In the meantime Canada has granted the Beauharnois Light, Heat, and Power Company a permit to construct a power canal between Lakes St. Francis and St. Louis, on the St. Lawrence River, to divert 40 000 sec-ft. for the development of an initial output of 500 000 h.p. The permit, however, provides that the canal shall be of sufficient size for navigation, and the whole development is made subject to subsequent additions to make it a part of the St. Lawrence Project should the treaty between the two countries be consummated. Work was commenced on this project in October, 1929.

Niagara Falls

(Canada and United States)

A Special International Niagara Board was created by Canada and the United States in 1925, to investigate the change which was being made in the course of the Niagara River, which it was reported threatened to ruin the beauty of Niagara Falls, and to formulate plans to correct this condition. The Board submitted its report on December 14, 1927, in which it recommended the construction of certain submerged weirs and the enlargement of certain channels to distribute the flow more uniformly over the Falls for the purpose of affecting the desired results and also of providing opportunity for increased diversions.

Following negotiations, a treaty was formulated and a protocol was signed on January 2, 1929, providing for the construction of the remedial works as recommended by the Special Board and for an additional diversion of 10 000 sec-ft. of water on each side of the river between October 1 and March 31 of the following year, for a period of seven years. The treaty of January 11, 1909, provided for a diversion by New York State of 20 000 sec-ft. and by Canada of 36 000 sec-ft.

The ratification of the treaty by the Senate was opposed by the City of Chicago. It is reported that the municipal authorities of Chicago maintain that the treaty should not be ratified until the negotiations for the St. Lawrence Project and the Illinois Waterway are completed, and, further, that the remedial works would lower the lake levels, and the diversion of an additional 20 000 sec-ft. would increase the flow from Lake Erie. This latter view is discounted by Army engineers.

What is said to be considered a victory by New York State in her fight to retain control of power development within the State, was the obtaining from the Niagara Falls Power Company (the beneficiary of the diversion of the additional 10 000 sec-ft. at Niagara Falls) of an agreement to withdraw all objections to rentals now being paid the State for waters, and an agreement on the part of that Company to pay an equitable rental for the use of the additional diversion at Niagara Falls and to seek from the State a license for the use of that water. It is stated that New York considers this a com-

plete recognition of the rights and sovereignty of the State to license power companies and to demand a rental charge for all water now being used and to be used under the treaty.

Delaware River

(New Jersey and Pennsylvania *vs.* New York)

The State of New Jersey has filed suit in the Supreme Court of the United States against the State of New York, to enjoin New York City from making certain diversions from the headquarters of the Delaware River which she has planned to augment her water supply. The State of Pennsylvania is to join New Jersey in the suit. The first hearing was set for January 6, 1930. The Court declined to appoint a master.

The plan of development as proposed by New York, provides for a supply of 600 000 000 gal. daily from the flood waters of five tributaries of the Delaware River, and 100 000 000 gal. daily from Rondout Creek, a tributary of the Hudson. This plan provides for the construction of five reservoirs and the necessary aqueducts and appurtenances to bring the water to New York City. The plan also provides for releasing certain quantities of water, when necessary, to maintain a certain specified minimum rate of flow, as was provided for in the last proposed compact. The contemplated development is wholly within the State of New York about 30 miles from the main stream, and affects 600 sq. miles of the total of 2 389 sq. miles of drainage area of the Delaware River in New York. It is maintained by New York that flood waters only are to be stored, and that due to releases from New York reservoirs the low flows will be greater after the development than at present.

New Jersey and Pennsylvania maintain that those States have a right to the undiminished flow of the river, and it is reported that they further allege that New York State is contemplating the development of power with some of the water diverted.

This controversy is one of several years standing, and it was anticipated that settlement would be made by compact. A compact was negotiated in 1925, was signed by the Commissioners appointed by the three States, and was ratified by the State Legislature of New York, but failed of ratification in New Jersey and Pennsylvania. Another compact was formulated in 1927. It was signed by the representatives of the three States, but again failed to be ratified in Pennsylvania and New Jersey although it was ratified by the New York State Legislature.

It is understood that the main objections of Pennsylvania to the compact as formulated were:

1.—The allotment of water as made was not equitable.
2.—The compact provided for the diversion of a large quantity of best quality water into other water-sheds.
3.—It provided for the surrender by Pennsylvania of its present control of important tributaries of the Delaware River, which are entirely within the State limits, to a super-State body.

The City of Trenton, N. J., was one of the principal objectors to the compact in New Jersey.

After failure to consummate a compact, New York City retained Attorneys Hughes and Davis to give their opinion as to the right of New York to make the proposed diversion. Both attorneys held in effect that if the facts were as they were purported to be, the Supreme Court would probably allow the diversion and provide for the payment of damages, if any, to lower interests; whereupon New York decided to proceed with the development, which action precipitated the suit.

It is believed the following portion of Mr. Hughes' opinion is of particular interest in the light of growing interest over the country regarding Federal *vs.* State control of unappropriated non-navigable waters. Mr. Hughes says:

"'Whether Congress has power to provide the diversion of navigable waters from one water-shed to another is a question which may be regarded as not yet finally determined' if 'Congress has this power it would be exercised only in interest of interstate commerce, that is, navigation.' Similarly the Secretary of War could not act except to protect navigation. Therefore unless the proposed diversion would injuriously affect navigation, 'the United States will not be entitled to complain.'"

The outcome of the suit should be of great importance to riparian right States, as heretofore no precedent has been established. Many future water supply developments in the East must be along lines similar to those proposed by New York, that is, involving riparian rights in two or more States.

Lake Michigan

(Pollution of Chicago Water Supply. Chicago and Indiana Towns on South Side of Lake)

Negotiations are under way between the City of Chicago and certain Indiana towns on the south side of Lake Michigan to provide for the elimination of the pollution of the Chicago water supply by phenol wastes from coke-oven plants in the Indiana towns. The pollution occurs when unusually strong winds blow from the south carrying the phenol across the lake in the vicinity of the intakes of Chicago's water supply system.

As an example of the amount of the pollution, it is reported that during the occurrence of strong winds in the latter part of 1927, it required 13.6 lb. of chlorine per 1 000 000 gal. for purification purposes while the normal quantity of chlorine necessary is 2 lb. per 1 000 000 gal. The excessive quantities of chlorine and phenol cause the water to have a bad taste.

It is reported that plans are already under way or completed for the elimination of the phenol nuisance in the Calumet and Michigan City Districts.

Chicago Diversion from Lake Michigan

The United States Supreme Court by a decision rendered on January 14, 1929, ended a 20-year controversy between the City of Chicago and all the Lake States, except Illinois and Indiana, regarding certain diversions that the city has been making from Lake Michigan for sewage dilution and other purposes. The controversy finally involved thirteen States, practically all the Mississippi River States supporting Chicago on the plea that the diversions

aided navigation along the Mississippi. The Supreme Court held in its decision that the diversion as made by Chicago was illegal; that no diversion was legal except in the interest of navigation; that the increase in diversion made by Chicago from 4 167 sec-ft. to 8 500 sec-ft. defied the authority of the National Government resting in the Secretary of War; and that Chicago must proceed with dispatch to remedy the condition. Provision was made for further hearings to determine the minimum quantity of water necessary to be diverted in the interests of navigation, and to determine the length of time that should be allowed the City of Chicago to reduce the diversions to that point.

Hearings to determine these questions were held before the Hon. Charles E. Hughes, Master, during 1929. Mr. Hughes submitted his report to the Supreme Court on December 17, 1929, in which he specified a certain program of construction of sewage treatment works that Chicago should follow to enable the diversion from the lake to be reduced from its present amount of 8 500 sec-ft. to a permanent amount of 1 500 sec-ft., on December 31, 1938. Mr. Hughes also recommended that Chicago should be required to install control works to prevent the reversal of flow through the Chicago River during storms; the plans for the control works to be approved by the Chief of Engineers of the War Department; and those works to be completed within two years after receiving the authorization of the War Department.

The plaintiffs in the case alleged that the diversion of water as made by Chicago from Lake Michigan interfered with navigation on the Great Lakes by lowering the surface of the lakes by as much as 6 in.

The carrying out of the provisions of the decision of the Supreme Court will necessitate, probably, the greatest expenditure of money ever made to conform to a Court decision regarding water matters. Chicago engineers estimate that the works necessary to carry out the Court order will cost $176 000 000. However, the Court decision was not important from the standpoint of precedent. It did not determine relative rights of riparian owners which is an important question in the East. The decision was based upon an act passed by Congress in 1899, which gave to the Secretary of War and the Chief of Army Engineers authority to prevent obstruction to navigation. However, the decision did state that Congress "may not arbitrarily destroy or impair the rights of owners by legislative action which has no real or substantial relation to the control of navigation or appropriateness to that end."

Rio Grande, Colorado, Tiajuana

(United States and Republic of Mexico)

Probably the most important and involved question concerning international streams in the United States is that of allotment of waters of the Rio Grande (from Fort Quitman, Tex., to the Gulf of Mexico), Colorado, and Tiajuana Rivers, between the United States and Mexico.

A large body of land is irrigated in Texas along the Lower Rio Grande. Several millions of dollars are now being expended in the further development, and more development is contemplated. Most of the water originates

in Mexico and comes to the Rio Grande through tributaries, the main ones of which are the San Juan and Salado. There are large areas of land in Mexico susceptible of irrigation from those streams. Development in Mexico is far behind that in the United States, but some development on a large scale has been started. The Don Martin Project being constructed by the Mexican Government will provide for the irrigation of about 165 000 acres of land from the Salado. A treaty is necessary to provide for a proper allocation of the water supply, or future Mexican uses might encroach upon present uses being made of the waters by American land owners.

On the Colorado River conditions are the reverse of those on the Rio Grande. The water supply originates in the United States, while there is a considerable acreage of land in Mexico being watered by the Colorado River which might be deprived of its water supply by future uses in the United States unless an allocation is made by treaty.

Tiajuana River meanders back and forth across the western end of the international boundary between the United States and Mexico. The City of San Diego, Calif., and water users in that vicinity need Tiajuana water; so do Mexican users. Due to the character of flow, storage is required. The Mexican Government is now building a reservoir for that purpose. An allocation of those waters should be made.

A commission was appointed by the United States, composed of Elwood Mead and Lansing H. Beach, Members, Am. Soc. C. E., and Mr. W. E. Anderson, to meet with a similar commission representing the Republic of Mexico, to discuss these matters and devise a basis for settlement. The Mexican Commission was appointed in 1927, while the American Commission had been in existence for some time.

The Joint Commission was very active in 1929, several meetings having been held. More are scheduled for 1930. No report has been made public as to the progress being made, but it is hoped the basis for an early settlement has been reached.

For some time the Rio Grande between El Paso, Tex., and Fort Quitman has been under discussion by the International Boundary Commissions of the United States and Mexico. The questions involved are flood control and means to prevent channel changes which have caused some difficulty in determining ownership of certain tracts of land. Considerable time was spent by the two Commissions in making detailed investigations and apparently an early settlement is in view. The American International Boundary Commission made a report to the Secretary of State in June, 1929, on the engineering feasibility of a plan to solve the problems involved.

Rio Grande

(Colorado, New Mexico, and Texas)

A series of conferences were held between these States at Santa Fe, N. Mex., beginning in December, 1928, and ending in February, 1929, for the purpose of formulating a compact providing for the allocation of the waters of the Rio Grande. The conferences were presided over by Col. W. J. Donovan, representing the United States.

It developed during the negotiations that it would be impossible at that time to draft a compact which would make a definite allocation of water satisfactory to all the interested States, due principally to the fact that the ultimate water supply of the basin which was to be divided, was not known.

Of the water-shed of the Rio Grande in Colorado 2 900 sq. miles constitute a closed basin that is not tributary to the Rio Grande, but may be made so by the construction of an outlet drainage canal tapping the area. Such canal would materially augment the quantity of water contributed by Colorado to the Rio Grande.

A temporary compact was formulated and signed by the Interstate River Commissioners for the respective States, providing for a condition of *status quo* on the river for a period of five years, during which time concerted effort would be made by the three States to bring about the construction of the drainage canal from the closed basin in Colorado, together with the construction of a storage reservoir at the Colorado-New Mexico State line, all at Government expense. After the construction of these works, or at the expiration of five years, further negotiations are to be entered into for the consummation of a permanent compact.

The compact provides for the construction of these works by the Federal Government. The claim of the three States upon the Federal Government is predicated upon the fact that some years ago the United States Government entered into a treaty with the Republic of Mexico whereby there was ceded to Mexico in perpetuity 60 000 acre-ft. per annum from the waters of the Rio Grande. This treaty was not the result of any legal obligation upon the United States, but was in the interest of international comity. In an opinion rendered at the request of the Department of State, Attorney General Judson Harmon said in regard to the validity of Mexican claims:

"Whether the circumstances make it possible or proper to take any action from considerations of comity is a question which does not pertain to this department; but that the question should be decided as one of policy only, because the rules, principles, and precedents of international law impose no liability or obligation upon the United States."

The treaty specifically states that Mexican claims were not conceded and it stipulated that the settlement was not to be construed as a precedent.

The three States contend that the 60 000 acre-ft. which were ceded to Mexico were taken from the common water supply of the three States for the benefit of the whole Nation (to preserve international comity and peace) and, therefore, the cost of construction of the outlet drain and reservoir provided for in the compact, and which will result in returning to the States the equivalent of the water ceded to Mexico, is an obligation of the United States Government.

The compact as formulated was ratified by the Legislatures of the three States. A bill now before Congress provides for the ratification of the compact by the Federal Government and for the construction of the outlet drain as provided for in that compact.

Colorado River

(Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming)

Progress of Negotiations Since July, 1927.—In an effort to reach an agreement on the division of the waters of the Colorado River allotted to the Lower Basin States by the Santa Fé-Colorado River Compact of 1922, further conferences were held between representatives of Arizona, California, and Nevada during 1927, but to no avail, the major difficulty being a difference of opinion as to the proper allotment of benefits derived from power that might be developed along the Colorado River.

The Swing-Johnson Bill, after many amendments and vicissitudes, passed the House of Representatives in June, 1928, and the Senate during the session of 1928-29. The bill as passed is termed the Boulder Canyon Project Act and among other things provides for the following:

1.—Construction of a dam at Boulder or Black Canyon of not less than 20 000 000 acre-ft. capacity to control floods, improve navigation, store water for use in the United States, and to generate power.
2.—An appropriation of $165 000 000 to construct the project, of which $25 000 000 was designated for flood control, the $25 000 000 to be replaced out of 62½% of any revenue in excess of the amount necessary to repay the Government for the remainder of the cost.
3.—That contracts shall be made by the Secretary of the Interior for the sale of power, and water in sufficient amount to replace the Government investment in the dam and power plants in fifty years, before construction is started, the power to be sold at a price "justified by competitive conditions at distributing points or competitive centers."
4.—That 37½% of any moneys collected by the Secretary of the Interior above the amounts due the Government, shall go to Arizona and Nevada by virtue of their natural resources being taken for a public service.
5.—Allotment of 300 000 acre-ft. of water to Nevada and 2 800 000 acre-ft. to Arizona for exclusive beneficial and consumptive use in perpetuity. That Arizona may annually use one-half of the excess or surplus waters unapportioned by the Colorado River Compact and all the Gila River.
6.—That the Act would become effective when seven States ratified the Colorado River Compact, but, failing this, it would become effective by proclamation of the President six months after passage, if six States had ratified the Compact.
7.—All provisions of the Act and the future operation of the project were made subject to the Colorado River Compact.

The Act also provided that the All-American Canal may be constructed, the cost to be paid by the lands benefited.

The Act was approved December 21, 1929. Arizona did not ratify the Colorado River Compact, but Utah did so in March, 1929, which provided the necessary six States. In June, 1929, President Hoover declared the Act effective.

When notice was given that bids would be received for power, the applications were greatly in excess of the available power. After the Secretary of the Interior made his announcement of the tentative allocation of power and the

price to be paid for it, some of the States, notably Arizona and Nevada, took exception to such allocation. Pending a further effort to reach an agreement between the Lower Basin States, the Secretary announced that no contracts for power or water would be let immediately, if Arizona, Nevada, and California would enter into further negotiations in an attempt to reach an agreement. Arizona had prepared a suit to be filed in the United States Supreme Court. The request of the Secretary was complied with, and Arizona refrained from filing her suit pending the outcome of conferences between the Lower States to start January 20, 1930. It is anticipated that if the Lower States fail to reach an agreement, Arizona will immediately file her suit in the Supreme Court of the United States. In the meantime no money can be appropriated for carrying out the purpose of the Act, since contracts for the sale of power and water have not been signed.

The Interstate Water Commissions of the Upper Basin States—Colorado, Wyoming, New Mexico, and Utah—held a preliminary conference in Denver, Colo., on December 5, 1929, for the allocation of the 7 500 000 acre-ft. of water set aside for the Upper Basin by the Colorado River Compact.

Due to the fact that some of the States did not have all their data prepared, the conference adjourned to be reconvened in the early part of 1930. From the preliminary discussion it is not anticipated that any great difficulty will be experienced in consummating a compact among these four Upper Basin States.

Laramie River

(Colorado and Wyoming)

Some discussions have taken place between the States of Colorado and Wyoming with respect to present uses of water in Colorado from the Laramie River, an interstate stream.

Some years ago as a result of a suit instituted by the State of Wyoming against the State of Colorado, the Supreme Court of the United States rendered a decision relative to the uses of the waters of this stream by the two States.

It appears from these negotiations that Colorado places a materially different interpretation on the decree of the Court than the State of Wyoming, which may require a construction of the decree by the Court to clarify the present situation.

La Plata River

(Colorado and New Mexico)

In 1922, Colorado and New Mexico ratified a compact providing for the division of the waters of the La Plata River, a small interstate stream heading in Southwestern Colorado and flowing into New Mexico. This compact is administered by the State Engineers of the States in question.

The provisions of the compact permit rotation of water between the two States during times of shortage. This practice has resulted in a recent suit instituted by one of the water users in Colorado for the purpose of enjoining the water officials of Colorado from continuing such practice, which it is alleged results in injury to the plaintiff. This suit will be watched with

interest since in reality it is a direct attack upon the validity of the compact which was the first one negotiated by Colorado with her sister States with respect to the use of waters of interstate streams.

It should be borne in mind that the aforementioned suit is not of an interstate or international character, but at present is an internal affair.

North Platte

(Colorado and Wyoming)

Negotiations have been carried on during the past two years between Colorado, Wyoming, and Nebraska with respect to the use of the waters of the North Platte River, which flows through the three States.

The Federal Government, through the Bureau of Reclamation, appears to be an interested party in this connection as a result of the construction of the Pathfinder Reservoir in Wyoming, and later of other reservoirs and canal systems in Eastern Wyoming and Western Nebraska. These Federal projects have an important bearing upon the equalization and administration of stream flow in Wyoming and Nebraska.

It is confidently anticipated that a successful termination of these negotiations will be had at a comparatively early date.

Arkansas River

(Colorado and Kansas)

Litigation between the States of Colorado and Kansas over the waters of the Arkansas River has been practically continuous for the past twenty-eight years. In the noted suit brought by Kansas against Colorado in 1901 the United States Supreme Court decided that although certain irrigation interests in Western Kansas had been injured by diversions of water from the Arkansas River in Colorado, that such diversions in that State had not exceeded its equitable share of the waters of this interstate stream, dismissed the case without prejudice against Kansas to re-institute suit at a later date if continued diversions in her judgment justified such action. Kansas has not elected to do so to date.

Almost immediately after the settlement of that suit, certain ditches in Kansas instituted suit in the Federal Court for the District of Colorado against a large number of ditches and reservoirs in Colorado, seeking to restrain the latter from diverting water in Colorado to their alleged injury in Kansas. The first of these suits was settled out of Court, but a later suit was instituted in the same Court by one of the Kansas ditches not a party to the former settlement. This condition resulted in Colorado in her sovereign capacity filing suit in 1929 against the State of Kansas for the purpose of requiring the latter State to enforce the provisions of the former Supreme Court decree and quiet further litigation by her agents. Testimony in this important case is now being taken before a Commissioner of the Supreme Court.

Negotiations between the Interstate River Commissioners of the two States for some years past looking to the formulation of an interstate com-

pact with respect to the uses of the water of this river, have to date failed in their objective and, as a result of the present suit, have been entirely discontinued.

Kootenay River

(Canada and Idaho)

Owners of reclaimed lands in Northern Idaho objected in the fall of 1929, to the proposed plan of the West Kootenay Power and Light Company of British Columbia, to construct a dam in Kootenay River at Granite, Idaho, on the plea that such a dam would cause the flooding of their lands. The development as proposed by the Power Company is for the purpose of providing additional power.

The International Joint Commission authorized the Company to make the necessary excavations for the dam, but stated that final decision would be withheld until data relative to possible damage were secured.

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PAPERS AND DISCUSSIONS

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STUDIES OF SHEAR IN REINFORCED CONCRETE BEAMS

Discussion*

By T. D. Mylrea,† M. Am. Soc. C. E.

T. D. Mylrea,‡ M. Am. Soc. C. E. (by letter).§—The writer has been impressed with the view, expressed by several contributors, that cracking and failure of reinforced concrete beams are synonymous. This is not necessarily the case. The occurrence of fine cracks means simply that the reinforcement is being stressed, and if reinforcement is present in the proper amount and distribution, such cracks need cause no apprehension. Prominent cracks may indicate one or more of several things. Wide vertical cracks, or more often, one wide crack in a region of low shear usually accompany stress beyond the yield point in the reinforcement. In simple beams they may indicate slip of the main reinforcement. Wide diagonal cracks between the supports and mid-points of simple beams generally mean slip of bar or crushing of concrete under the bends of the web reinforcement. These cracks are particularly dangerous, for they show that the load limit of the beam is reached, and that real failure, even under a decreasing load, may follow quickly. Thus, cracking may or may not mean danger. The cracking is not necessarily dangerous, if the reinforcement is adequate.

Mr. Godfrey has presented a number of interesting points. For example, he questions the validity of the 45° assumption in the development of the formulas for web reinforcement.‖ If a reinforced concrete beam were truly homogeneous, such cracks as occurred would tend to form at right angles to the tension stress trajectories. If the beam could be modified so that the horizontal components along all tensile stress trajectories were resisted by

* Discussion of the paper by T. D. Mylrea, M. Am. Soc. C. E., continued from November, 1929, *Proceedngs*.

† Author's closure.

‡ Prof., Bldg. Constr., Carnegie Inst. of Tech., Pittsburgh, Pa.

§ Received by the Secretary, January 16, 1930.

‖ *Proceedings*, Am. Soc. C. E., April, 1929, Papers and Discussions, p. 1091.

the horizontal steel, then the diagonal tension and diagonal compression components of the vertical shear on any vertical section would be a maximum on planes inclined at 45° to the vertical, and cracks above the steel and below the neutral axis would occur at an angle of 45 degrees. In regions of low vertical shear, where they are not dangerous, cracks would be slightly inclined. It is a fact that in simple beams cracks generally occur in this manner. Where, owing to slip of the main reinforcement, a dangerous diagonal crack occurs, the crack is more nearly horizontal for some distance along the bar, gradually approaching 45°, and then tending toward the horizontal again. Even here, where vertical stirrups would be of little help, the 45° assumption as to the direction of crack is on the safe side.

In continuous beams the stress trajectories become horizontal over the supports, and vertical cracks may form in the top of the beam at the face of the support. Within the angle formed by the face of the support and a line extending at 45° from the junction of the lower surface of the beam and the face of support, cracks will tend to form at angles between the vertical and 45 degrees. Fine cracks within the 45° line are not necessarily dangerous, for, as Mr. Godfrey states,* "with the top and bottom rods firmly anchored into the support, a large shear can be carried by the concrete". The resistance to the formation and development of these cracks is furnished by the horizontal negative reinforcement, not by the web steel. If the negative reinforcement is deficient in amount or in anchorage into the support or out into the beam proper, these cracks will develop, and no type of web reinforcement will prevent trouble. This, however, is no concern of the web reinforcement, for it can only reinforce the web outside the 45° line. Thus, again, the 45° assumption seems not erroneous for use in the design of the web steel. Mr. Godfrey mentions† the weakness at this point, and so does Mr. Werner‡, but if the horizontal steel were deficient the diagonal bars recommended by Mr. Godfrey could function only by sidewise bearing in the concrete, which he, himself, points out as being ineffective. It seems to the writer, then, that while Mr. Godfrey's method of web reinforcement is undoubtedly a good one, the 45° assumption is satisfactory as a basis for working formulas.

Mr. Godfrey also mentions§ the difficulty of anchoring bars properly and compares an anchorage to the end detail of a truss member. In this the writer heartily concurs; but because he had presented a former paper‖ dealing exclusively with this subject, he did not develop the point further at this time.

The writer has observed a curious phenomenon in simple beams tested to destruction. When uniform loads were used, the dangerous diagonal tension crack formed at about the quarter-point of the span, whereas when concentrated loads were used the important crack ran diagonally upward from the reinforcement toward the load point at an angle of about 45 degrees. Mr. Turner's discussion¶ may hold the clue to this phenomenon. It seems to the

* *Proceedings*, Am. Soc. C. E., April, 1929, Papers and Discussions, p. 1093.
† *Loc. cit.*, p. 1091.
‡ *Loc. cit.*, November, 1929, Papers and Discussions, p. 2399.
§ *Loc. cit.*, April, 1929, Papers and Discussions, p. 1093.
‖ *Journal*, Western Soc. of Engrs., January, 1926.
¶ *Proceedings*, Am. Soc. C. E., April, 1929, Papers and Discussions, p. 1094.

writer that if stirrups are necessary at all in simple beams they should be carried at least to the quarter-points.

It was not the writer's intention to bring bi-axial strain into the discussion, as suggested by Mr. Feld,* for he feels that web reinforcement can be designed effectively and economically without such complication. Professor Cross has well summarized some of the writer's ideas in the last paragraph of his discussion;† but it is the writer's intention also to point out that when steel of a high elastic limit is used, great progress is still possible in reinforced concrete design. If the designer wishes to take advantage of these possibilities, he must constantly keep in mind all the precautions pointed out, even though, as Mr. Eckles states,‡ some of them may appear to be extreme.

* *Proceedings*, Am. Soc. C. E., April, 1929, Papers and Discussions, p. 1103.
† *Loc. cit.*, August, 1929, Papers and Discussions, p. 1652.
‡ *Loc. cit.*, April, 1929, Papers and Discussions, p. 1102.

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PAPERS AND DISCUSSIONS

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PRE-DETERMINING THE EXTENT OF A SEWAGE FIELD IN SEA WATER

Discussion*

BY A. M. RAWN AND H. K. PALMER, MEMBERS, AM. SOC. C. E.†

A. M. RAWN‡ and H. K. PALMER,§ MEMBERS, AM. SOC. C. E. (by letter).‖—The writers' acknowledge with thanks the discussions of their paper. Some of these discussions require no comment other than to state that they are helpful in pointing out the limitations to be set about the formulas and that they contribute additional information supplementing the original investigation or allied to it.

Mr. Howland¶ raises a question regarding the time factor used in developing the formula for spread of the sewage field. The writers state that the time used was that of the initial spread. It was found that the edge of the field advanced with the same relative velocity as that of the continuing field; that is, the velocity of flow past a given point on the raft or plank was reasonably constant for constant conditions. So long as the field thickness remains constant, which observations indicate to be true, this would necessarily be so.

It is quite impossible to obtain a series of observations yielding consistent values of the exponent of x in the equation,

$$V = \frac{F}{x^n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (39)$$

because the forces causing the spread of the field are small and slight disturbances materially affect the velocities.

Fig. 9 shows a series of four sets of curves drawn by assuming a field to be spreading in concentric circles of equal dilution in absolutely still water.

* Discussion of the paper by A. M. Rawn and H. K. Palmer, Members, Am. Soc. C. E., continued from December, 1929, *Proceedings*.

† Authors' closure.

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§ Chf. Draftsman, Los Angeles County Sanitation Dists., Los Angeles, Calif.

‖ Received by the Secretary, December 26, 1929.

¶ *Proceedings*, Am. Soc. C. E., October, 1929, Papers and Discussions, p. 2221.

They are drawn with the same value of C for all functions. This emphasizes clearly the effect of the exponents. In actual cases these lines would not intersect at one point, but would be parallel to the lines shown. At any distance, x, from the center the quantity of diluted water passing the ring would

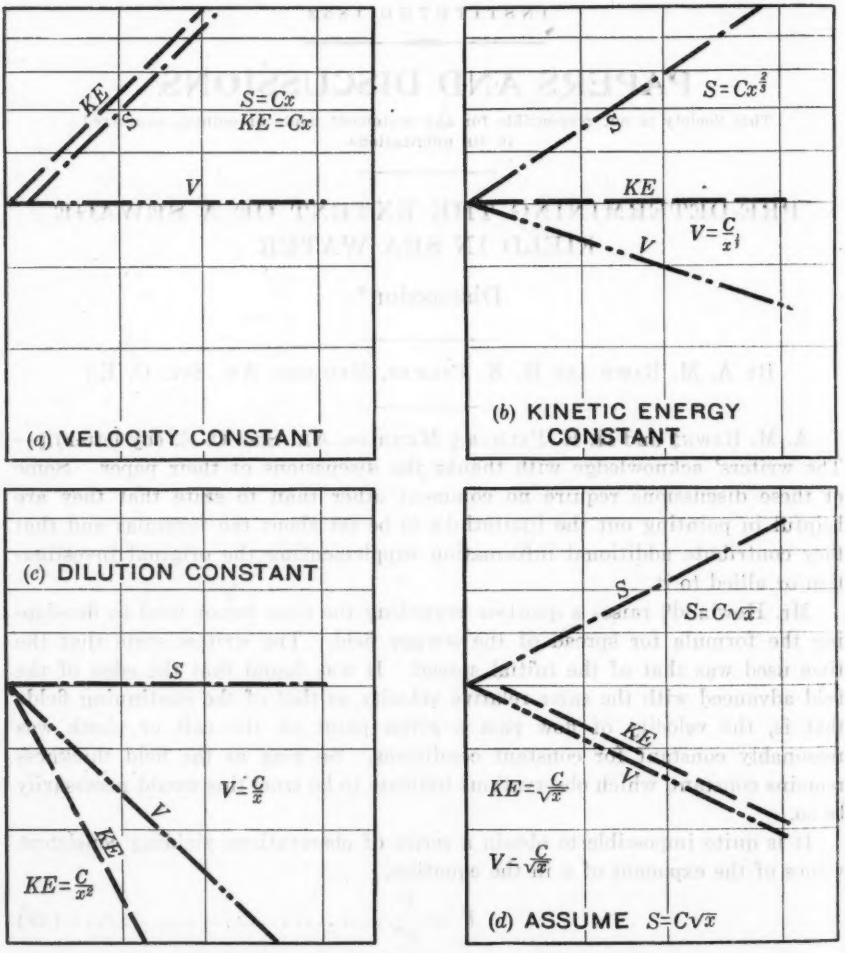

FIG. 9.—CURVES OF DILUTION, VELOCITY, AND KINETIC ENERGY.

be QS, and the velocity would be as given by Equation (19).* Combining constants, this equation becomes:

$$V = C\frac{S}{x} \qquad (40)$$

which involves three variables and is indeterminate unless assumptions are made.

* *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, p. 1179.

Kinetic energy is proportional to the quantity and the square of the velocity and by properly combining all constants an equation may be written:

$$K E = C_1 S V^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (41)$$

A new variable is introduced in Equation (41) and the equation remains indeterminate. By making further assumptions, certain permissible values may be shown.

Case 1.—Assume that V is constant (see Fig. 9 (*a*)); then:

$$K E = C_2^1 x \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (42)$$

and,

$$S = C_3 x \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (43)$$

in which, x equals the horizontal distance from the center of the rising column at the surface to any point in the field. According to Equation (42), kinetic energy increases with distance, which is an impossible situation as there is no source of energy.

Case 2.—Assume that the kinetic energy is constant (see Fig. 9 (*b*)); then:

$$S = C_4 x^{\frac{2}{3}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (44)$$

and,

$$V = \frac{C_5}{3\sqrt{x}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (45)$$

This is an ideal condition in which there would be no loss of energy. It constitutes the upper limit for the velocity and the exponent of x lies somewhere between 0.33 for the second assumption, and 1.00 for the third assumption.

Case 3.—Assume that the dilution is constant (see Fig. 9 (*c*)); then:

$$K E = \frac{C_6}{x^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (46)$$

and,

$$V = \frac{C_7}{x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (47)$$

In this instance, the kinetic energy decreases rapidly as might be expected, due to friction between the clear sea-water surface and the sewage field; but there is no dilution, which experiment disproves. It does not fit the facts and may be considered as the opposite limit to Case 2.

Case 4.—Assume that $S = C_8 \sqrt{x}$ (see Fig. 9 (*d*)); then:

$$K E = \frac{C_9}{\sqrt{x}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (48)$$

and,

$$V = \frac{C_{10}}{\sqrt{x}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (49)$$

This is a reasonable value of velocity, and while it may not be absolutely correct, it more nearly generalizes the facts determined by the writers than any other.

In the study of the spread of actual sewage fields in sea water, the dilution was measured by the chlorine titration method and the writers feel that without extreme care and refinement, such as might be obtained in a laboratory under expert care and supervision, this method has a limiting value for determining dilutions of $S = 75$, and that the determination of values of $S > 40$, is somewhat uncertain. In Equation (22)* the limiting value for $S = 212$ is obtained by substituting three known values in the equation, namely, S_0 and X_0 found from depth, quantity, and direction of discharge, and X from the bacteriological survey of the actual field at Hyperion. Thus, it is seen that $S = 212$ is not a value determined by analysis of the sewage, but that it is a computed value and is dependent upon the exponent of x.

Expressing Equation (17)† as,

$$t = \frac{1}{n\,F} X^n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (50)$$

and conforming to the reasoning given in the text, Equation (22) becomes,

$$S = S_0 \left(\frac{x}{X_0}\right)^{2n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (51)$$

or,

$$x = X_0 \left(\frac{S}{S_0}\right)^{\frac{1}{2-n}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (52)$$

Stating the value of n equal to 1.5, as in the text, this becomes,

$$x = X_0 \left(\frac{S}{S_0}\right)^{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (53)$$

but if $n = 1.6$ then,

$$x = X_0 \left(\frac{S}{S_0}\right)^{2.5} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (54)$$

Again referring to the computed field at Hyperion, by use of Equation (22) the field is found to have a limiting value of $S = 212$. Had the exponent, 0.417 (corresponding to the value of $n = 1.583$), been used instead of 0.50, the value of S expressed by Equation (22) would be 135. The value, $S = 212$, was attained by assuming S_0 equals 14, and, as long as the value of S_0 is nearly this, it can be seen that it makes little difference whether the exponent 0.417 or 0.50 is used. For larger values of S_0 the x distance obtained from the use of the smaller exponent will be less than that if 0.50 is used. Therefore, the formulas and diagrams given in the text err on the side of safety, if at all, and the writers feel that their use is justified until extensive experiments offer the substitution of other coefficients and exponents. One of the best series of measurements, using nineteen floats, gave an average equation of $t = 0.097x^{1.53}$.

In determining the behavior of a sewage field influenced by an ocean current, the writers have assumed that dilution is due to the relative motions of that field and the underlying moving salt water; and that in the process of initial dilution or during the rise of the sewage to the sea-water surface the

* *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, p. 1179.
† *Loc. cit.*, p. 1178.

(a) CROSS SECTION OF JETS AT SURFACE
(b) CROSS SECTION OF JETS 15 FEET BELOW THE SURFACE
(c) CROSS SECTION OF JETS 30 FEET BELOW THE SURFACE

FIG. 10.—HORIZONTAL CROSS-SECTIONS OF JETS SHOWING PROBABLE BEHAVIOR OF 116 CUBIC FEET PER SECOND OF SEWAGE ISSUING FROM DEER ISLAND OUTLET DURING ITS INITIAL DILUTION.

surrounding sea water will impart enough of its motion to the sewage so that the horizontal component of the rising cone just below the ocean surface will equal the velocity of the ocean current.

Mr. Eddy* has pointed out the erroneous assumptions made as to the design of the Deer Island Outfall. The writers acknowledge the correction and since receiving Mr. Eddy's notes have procured a complete copy of the plans of this Outfall, as well as the descriptive paper by Mr. R. W. Loud. Despite the fact that the writers were materially in error regarding this design, their statements relating to the probable distance of travel of the sewage field are not greatly in error. In his analysis of the Outlet in operation, Mr. Eddy has incorrectly made assumptions as to the probable initial dilution and final distance of travel in calm water, having overlooked the effect of mutual interference of the jets.

Fig. 10 shows the probable pattern of cross-sections of the sewage jets, taken at the sea-water surface and at 15 ft. and 30 ft. below the surface. Interference between the jets begins to occur 30 ft. below the sea-water surface (see Fig. 11) and there is really more of the rising column surface area in contact with the surrounding water at the 30-ft. level than at either 15 ft. below, or as the combined rising columns reach the surface.

By the time the sewage reaches the surface it is substantially one flat jet (see Fig. 10(*a*)), and while the experiments and observations from which the formulas were derived, were not carried sufficiently far to assure an accurate determination of the value of S_0 for this particular case, there follows from the formula a relationship between the area of the rising column exposed to the surrounding sea water and the value of S_0 at the surface. Taking into account the merging of the columns approximately 30 ft. below the salt-water surface, and the decreased periphery at about this elevation (see Table 10) the writers would state that the probable value for S_0 under conditions of flow as indicated by Figs. 10 and 11 is 25 as compared to 21 used by the writers† and 42 by Mr. Eddy.‡

TABLE 10.—Comparison of Actual with Theoretical Periphery.

Actual periphery, in feet. (1)	Theoretical periphery, in feet. (2)	Ratio, Column (1) / Column (2). (3)	Remarks. (4)
255	684	0.37	Cross-section of jets at surface.
230	521	0.44	Cross-section of jets 15 ft. below surface.
256	354	0.72	Cross-section of jets 30 ft. below surface.

Analysis of the Deer Island Outlet indicates that 116 cu. ft. per sec. will not flow from fourteen outlets, but only the first eleven as illustrated in Fig. 11. This is also indicated in Mr. Loud's paper,§ which describes an examination

* *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2705.

† *Loc. cit.*, May, 1929, Papers and Discussions, p. 1187.

‡ *Loc. cit.*, December, 1929, Papers and Discussions, p. 2706.

§ "The Metropolitan Sewerage Works," by R. W. Loud, *Journal*, Boston Soc. of Civ. Engrs., October 8, 1923, p. 360.

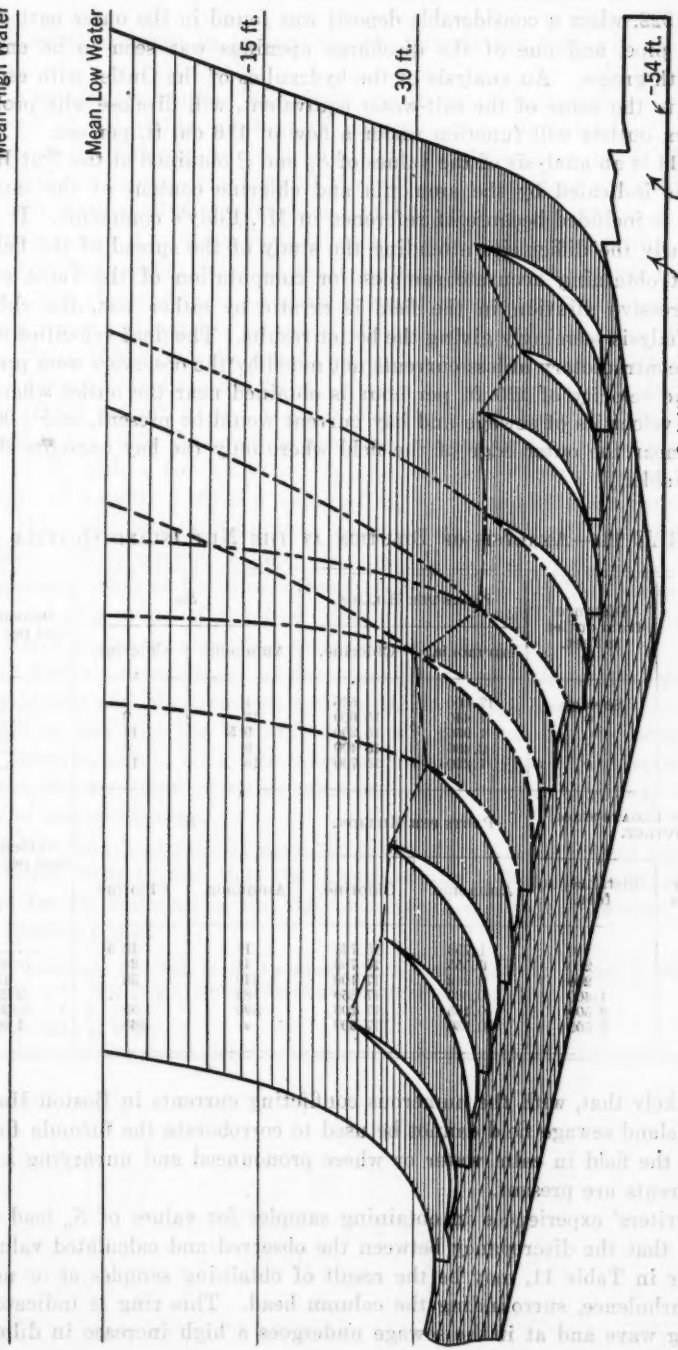

FIG. 11.—PROFILE AND ELEVATION SHOWING PROBABLE BEHAVIOR OF 116 CUBIC FEET PER SECOND OF SEWAGE ISSUING FROM DEER ISLAND OUTLET DURING ITS INITIAL DILUTION.

made in 1922, when a considerable deposit was found in the outer part of the discharge pipe, and one of the discharge openings was seen to be entirely choked with grease. An analysis of the hydraulics of the Outlet with especial reference to the value of the salt-water equivalent, will disclose why probably only eleven outlets will function under a flow of 116 cu. ft. per sec.

Table 11 is an analysis of the values of S_0 and S obtained at the Nut Island Outfall, as indicated by the ammonia and chlorine content of the samples. The table is included because of reference in Mr. Eddy's comments. It illustrates clearly the difficulties attending the study of the spread of the field, as well as of obtaining accurate samples for computation of the value of S_0. The progressive dilution in the field is erratic by either test, the chlorine content analysis seemingly giving the better results. The float velocities noted, are quite contradictory unless currents not noted by the observers were present, in that the velocity of 120 ft. per hour is obtained near the outlet where the combined velocities of sewage and bay current would be present, and 4 000 ft. per hour near the outer edge of the field where only the bay currents should be appreciable.

TABLE 11.—Analysis of Dilution at the Nut Island Outfall.

Time.	Distance from outlet, in feet.	Parts per Million.		S_0.		Velocity, in feet per hour.
		Ammonia.	Chlorine.	Ammonia.	Chlorine.	
8:30	Sewage	17.600	535	1	1	.....
9:13	0	1.440	15 600	13	9	.....
9:33	0	1.950	16 200	9.5	14	.....
9:53	0	2.400	15 400	8	8	.....
10:13	0	1.220	15 700	16	11	.....
Travel of Floats from Outlet.		Parts per Million.		S.		Velocity, in feet per hour.
Time, in hours and minutes.	Distance, in feet.	Ammonia.	Chlorine.	Ammonia.	Chlorine.	
0	0	1.753	15 725	11	10.5	.....
0:30	200	0.555	16 700	41	24	400
1:00	260	0.242	17 100	140	56	120
1:30	1 400	0.330	17 650	88	....	2 280
2:37	2 500	0.165	17 200	390	85	980
2:52	3 500	0.130	17 300	∞	169	4 000

It is likely that, with the numerous conflicting currents in Boston Harbor, the Nut Island sewage field cannot be used to corroborate the formula for the spread of the field in calm water or where pronounced and unvarying known ocean currents are present.

The writers' experiences in obtaining samples for values of S_0 lead them to believe that the discrepancy between the observed and calculated values of this factor in Table 11, may be the result of obtaining samples at or near a ring of turbulence, surrounding the column head. This ring is indicated by a standing wave and at it the sewage undergoes a high increase in dilution;

so that samples taken in or immediately outside the ring will yield erratic results.

The writers experienced great difficulty in obtaining samples directly from the head of the rising columns of sewage outlets in operation, principally because of the difficulty of rowing a boat into the column head. It is especially difficult to cross the ring of turbulence surrounding the column head. It is still more difficult to obtain samples from the rising column below the sea surface, and it is quite possible, even approaching a probability, to obtain specimens from either location that are extremely erratic, even if carefully taken. The rising column of sewage is not a homogeneous mass of sewage and sea water until it has moved at least a short distance from the column head. Fully 10% of all the samples taken in the experiments with small controlled outlets, was discarded by the writers as being too erratic for use.

Mr. Eddy refers* to two tests at New Bedford, Mass., on August 9 and September 24, 1915. Depending upon the position of the tide, the theoretical value of S_0 with a flow of 17 cu. ft. per sec. would vary between 9 and 15. The test of August 9 gives a value of $S_0 = 15$ and that on September 24, $S_0 = 111$. The test of September 24 is probably the result of obtaining an extremely dilute portion of the cone which, as has been stated, is not a homogeneous mass at the time it reaches the surface. A long series of observations of this value at the New Bedford Outlet would probably disclose a great many instances departing radically from the calculated value.

Mr. Fuller's description† of the operation of the diffusers on the Passaic Valley Outlet and Mr. Goudey's comments‡ on sewage from high velocity outlets, are in line with the writers' idea of the proper design for ocean outlets. Care, however, should always be taken to prevent mutual interference of rising columns, the tendency of which must be to decrease the extremely important factor of initial dilution.

To Mr. Allen's comment§ upon the limitations to be set about the formula, the writers wish to add that the formulas are useless, or nearly so, unless all the factors influencing the rise and spread of the sewage field are carefully predetermined.

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* *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2707.
† *Loc. cit.*, September, 1929, Papers and Discussions, p. 1925.
‡ *Loc. cit.*, p. 1934.
§ *Loc. cit.*, p. 1926.

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PAPERS AND DISCUSSIONS

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THE PLANNING OF CAPITAL CITIES: DENVER, COLORADO

Discussion*

By George H. Herrold, M. Am. Soc. C. E.

George H. Herrold,† M. Am. Soc. C. E. (by letter).‡—The planning of a capital city requires a different conception of functions than that of the ordinary commercial or manufacturing city, although the plan must provide for those necessary adjuncts to city life—banking, retail business, industry, transportation, and housing. In considering a capital city there must be a clear thought of its political character. It is the State's city; the seat of Government; the home of certain elected officials representing the Commonwealth; and the people of the State have an interest centered in this city that is dominant and must be recognized.

The State Capitol Building is and should be of fine architecture. Its satellite office buildings for housing the various State activities should be placed to form an architectural grouping, a State Civic Center, noted for the nobility of its structures. Here is located the Governor, the State Supreme Court, and certain Constitutional officers, such as the Secretary of State, State Treasurer, and State Auditor. The members of the Legislature (and these members are of no small number) must be properly housed during the Legislative session, which may be for one-third of the year. All these people must be provided with offices of a type and character consistent with the dignity of a great State.

In addition to the business of Constitutional officers, there are many activities carried on by the State Government and under State supervision which are not found in any other city. In general, there are the following departments which require buildings to house officials, their technical and clerical forces and equipment: The State Automobile Department; the State Depart-

* Discussion of the paper by S. R. De Boer, Esq., continued from December, 1929, *Proceedings*.

† Managing Director and Engr., The City Planning Board, St. Paul, Minn.

‡ Received by the Secretary, December 31, 1929.

ment of Agriculture; the Bacteriological Laboratories of the State Department of Health; the Adjutant General's Department; the State Highway Department with its locating, construction, and maintenance engineering departments, drafting rooms, testing laboratory, and purchasing department; the Department of Conservation; Drainage Department; Geological Survey; Forestry Department; the State Dairy and Food Department with chemical laboratories; the State Department of Education; the Grain Inspection Department; the State Department of Health, Division of Preventable Diseases; and the State Department of Health, Division of Sanitation, including the engineering forces for inspection and supervision of construction of sanitary work, such as sewage disposal.

There are also the State Immigration Department; State Department of Insurance; Labor and Industrial Commission; the Livestock Sanitary Board; the Nursery and Orchard Inspection Service; the State Nurses Examining Board; the Professional Engineers Licensing Board; the Department of the Public Examiner; the Department of Public Property; the Department of State Parks; the Railroad and Warehouse Commission with its technical staff; the State Securities Commission; the Surveyor General's Office; the State Tax Commission; the Game and Fish Department; the Reforestation Service; the Department of Weights and Measures; the Division of Banking; the State Sanitorium Advisory Commission; U. S. Department of Commerce Office; Board of Control; Feed Inspection; State Humane Society; State Inspection of Hotels; State Board of Investments; State Boiler Inspector's Office; the Board of Pardons; Department of Rural Credit; State Weed Inspector; and the State Law Library.

To add still further to the political atmosphere of a capital city, the Federal Government is here represented by the U. S. District Attorney and the Federal Court, the U. S. Marshal, Customs Office and Internal Revenue Officials, the Prohibition Administration Service, the U. S. Bureau of Animal Industry, the U. S. Agricultural Bureau of Markets, the Army and Navy Recruiting Offices, the U. S. Civil Service, U. S. Veterans Bureau and Veterans Hospital, the U. S. Weather Bureau, the Meteorological Station at the Airport, the U. S. Engineer's Office, the U. S. Bureau of Public Roads, the Secret Service, Public Health Service, Feed and Grain Inspection, Food, Meat, and Drug Inspection, Banks of the Federal Reserve and Land Bank System, and the U. S. Forest Experiment Station.

All the people in these departments have a governmental or political complex. They are interested in Government, its personnel and its method of doing business. Their engineering and architectural conceptions are based on governmental practices. They are a group who think along different lines and who have a different viewpoint from those engaged solely in trade and commerce.

A proper consideration of the housing of these departments leads to important and rare possibilities in the matter of location and design. All have distinct functions and require a definite type of office space. They should be located for the convenience of the citizens of the State who transact business in these departments and for the convenience of the officers

themselves for inter-communication. In fact, a large number of the people going and coming by train, bus, automobile, and air have some business with the State or Federal Government, or its various governmental departments, and they travel to and from the capital city on Government business; their secondary interests are social, other interests and business being incidental.

The streets leading to the Capitol and Capitol grounds should be of special design. They should have a cross-section for two or three roadways, separated by park strips, two wide one-way pavements, wide sidewalks, ample boulevards—all carefully landscaped; or three roadways, one major traffic lane, with side service roadways to serve abutting buildings. This requires a way of considerable width which is necessary in a Capitol group. The buildings will be of a monumental character, the streets must be wide and spacious, the street appurtenances must be designed in a generous way, and the public utilities such as sewage, water, message, heat, light, and transportation require special engineering treatment. The natural development along such an esplanade would be buildings of public and semi-public character, such as club houses, churches, lodge temples, hotels, theaters, and small shops of a high-class character. Retail business, however, should be on parallel and cross streets, in order that it may carry on the same as in any city and develop its own characteristics and spirit of business, separate and distinct from the State Capitol development. These things are controlled by proper zoning.

To carry out the idea of a State Civic Center there must be whole-hearted co-operation between the State Department in charge of grounds and development for the State and the City Planning Department of the city. The thoroughfare plan of the city should be co-ordinated with the Capitol approaches and so designed as to create fine vistas. The zoning of traffic is also necessary so that heavy trucking and commercial vehicles may have streets of their own on which to travel, and not be required or permitted to move over the esplanades and semi-parkways designed for approaches to the State group.

The State Civic Center is a unique and interesting development, superimposed upon the commercial district of the city and so placed that it will not interfere with its commercial expansion. At the same time, it should be the show place within the business center or adjoining it.

Capital cities are peculiarly political regardless of their commercial or manufacturing interests. The social life is a political social life and the State's activities will more or less dominate the character of the city despite other conditions.

As pointed out by Mr. De Boer,* the people of a Republican Commonwealth are no longer interested in diamond-studded uniforms or decorations for their officials. They have transferred their admiration and allegiance to fine architecture as depicting the spirit, culture, vision, and economic importance of the State. They demand architecture of rare distinction in a pleasing setting. They are style conscious in architectural motifs and the design and placement of State edifices. The buildings must have beauty both inside

* *Proceedings*, Am. Soc. C. E., August, 1929, Papers and Discussions, p. 1548.

and outside, and the grounds must give an air of spaciousness brought about by fine landscaping and the proper spacing of buildings, forming a major development of the city. The people of a capital city are beginning to recognize these things, and the people of a State are impressing it upon the people of the capital city that there must be full co-operation in the development of the Capital Civic Center, which will place both the city and the State before the world as built by a people of vision and engineering intelligence.

St. Paul is the capital city of Minnesota. It is a metropolitan city, and the fourth or fifth largest capital city in the United States—the 1930 census will determine which. It has one of the finest Capitol plans of any city in the United States, except the Nation's capital—Washington. When Mr. Cass Gilbert was supervising the construction of the Capitol in 1903, he made tentative sketches of the possibilities of the approaches to Capitol Hill. In 1907 he was definitely employed by the City of St. Paul to prepare the State Civic Center Plan so that the city itself in all its proposed street widenings, in the acquirement of down-town parks or public squares, and in the construction of public buildings, could co-ordinate them with the Capitol Plan. During the years intervening the State Historical Building was constructed and grounds have been acquired from time to time in accordance with this plan. Nothing has been done by the City of St. Paul which would interfere in any way with the complete development of the State Civic Center.

A State Office Building Commission authorized to expend $1 500 000 for housing State offices has just referred back to the Legislature the question of location and number of buildings. This was brought about by State-wide protest against proceeding without first adopting a State Capital City Plan.

The question of the State's interest in a State Civic Center has been settled in Minnesota, and after the Legislature meets in 1930 future development of Minnesota's capital city will be made in accordance with a plan.

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PULVERIZING OF SEWAGE SCREENINGS AT BALTIMORE, MARYLAND

Discussion*

By N. T. Veatch, Jr., M. Am. Soc. C. E.

N. T. Veatch, Jr.,† M. Am. Soc. C. E. (by letter).‡—This interesting paper describes a process which is new as far as recent sewage disposal practice is concerned, and is especially valuable because it falls in the class of studies that furnish actual operating data. Such contributions furnish the groundwork for real advance in the art.

The disposal of the grosser solids in sewage has long been a matter of concern, and many ideas have been presented to care for this part of the process. In 1894, an English patent was issued to one "Ives"; it involved a circular screening chamber into which sewage was to be introduced on a tangent.§ The paper, excreta, and other solid matter were to be whirled against baffle-plates and "to a large extent comminuted" and, finally, to be returned to the sewage ahead of the screen. Rideal states (1901) that "agitation with pulverization of the organic solids has been the subject of many patents."§

The general idea of pulverizing the sewage solids is, therefore, not a particularly new one, but its application in connection with modern sewage disposal works is novel and offers an additional treatment process worthy of consideration.

Any method of disposing of screenings which will prevent their accumulation and keep them out of sight, and which will eliminate the necessity of incineration or burial, will certainly be favored in many instances even if it is somewhat more expensive. The odor-elimination feature of this process

* Discussion on the paper by C. E. Keefer, M. Am. Soc. C. E., continued from January, 1930, *Proceedings*.

† Cons. Engr. (Black & Veatch), Kansas City, Mo.

‡ Received by the Secretary, December 30, 1929.

§ "Sewage and the Bacterial Purification of Sewage," by Samuel Rideal, Second Edition, p. 131.

has not been given a value by the author in his comparative cost estimates,* and, in many cases, this would undoubtedly change the picture materially.

The question of odor control at sewage disposal plants is becoming more and more important and, as one writer has very aptly stated,† "good effluents may be a thing of beauty to the State Health Department and a joy forever to the Izaac Walton League, but there is still another social group which must be satisfied", namely, the residents of the disposal plant neighborhood. Certainly this feature should be given full consideration in a study of the economics of the process.

That fine screenings may be digested successfully has been amply demonstrated by Rudolfs and others, and, while the pulverized or macerated coarse screenings will probably contain less nitrogen and more carbon than fine screenings alone, the total volume of the pulverized screenings is such a small portion (1.24%) of the total plant sludge that it may be expected to have no material effect on digestion. A small increase in gas production may be expected if the pulverized screenings are digested, but this increase is too small to have any particular weight.

Based on a gas production of 5.7 cu. ft. per lb. of dry solids digested (the figure indicated by the Milwaukee experiments on the digestion of fine screenings) and on the author's figures* on the quantity of pulverized screenings produced at Baltimore, the additional gas production will equal 5 940 cu. ft. per day, or 108 cu. ft. per 1 000 000 gal. of sewage. This estimate is probably high since the character of the material in question differs considerably from that of fine screenings.

If the pulverized screenings are to be added to the sewage and put through the plant for treatment, the effect on the treatment processes must be considered, of course; but, in view of the fact that the total amount added in this manner is only 1.24% of the total plant sludge, and since the material is largely inert matter which may be settled out of the sewage, it is doubtful whether this addition will have any material effect on the final treatment processes. This amount of material could be added to the sewage during the night or at other off-peak hours, so that the maximum organic load would not be increased at all and the average load would be increased only slightly.

It would be interesting to know the effect of the pulverized screenings on scum formation in settling tanks, and the extra operation cost, if any, on that account.

The author has discussed the advantages and disadvantages of this process very clearly and frankly, and his statement‡ that "the grinding of sewage screenings in a suitable pulverizer affords a means of disposing of them where local conditions favor such a method" covers the field admirably.

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* *Proceedings*, Am. Soc. C. E., September, 1929, Papers and Discussions, p. 1765.

† "Sewage Works Odors and Their Control," by Morris M. Cohn, *Sewage Works Journal*, Vol. I, No. 5, October, 1929, pp. 568-577.

‡ *Loc. cit.*, p. 1771.

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FILTERING MATERIALS FOR WATER AND SEWAGE WORKS

PROGRESS REPORT OF THE COMMITTEE OF THE SANITARY ENGINEERING DIVISION

Discussion*

By Messrs. Earnest Boyce and Herbert F. Kriege

Earnest Boyce,† M. Am. Soc. C. E. (by letter).‡—All studies of biological filters might properly be the subject of study by this Committee in so far as the character of the filter material influences efficiency. It might be suggested that the Committee could render a real service to the designer by making a study of all research data in this field, this material to be studied carefully and correlated so that sanitary engineers might know the established facts. Much excellent work has been done in the past by unrelated agencies, and there is a need for a compilation of this material, eliminating that which subsequent research study has shown to have been erroneous and including all accepted work that is pertinent to the activity of this Committee.

Unfortunately, a great deal of the research work that has been done on biological filters is not easily available, and unless a study is made that will bring together all pertinent data, much useful information will be lost to the designer. Incidentally, such a study would perhaps suggest the importance of having new design data to cover certain phases of the problem when the available data are not complete or conclusive.

A complete study of biological filters involves both the physical and the biological aspects of the problem of providing a suitable place for the oxidation of organic matter in sewage. Many of the data developed from experimental and other past studies have diminished value because too little attention was

* Discussion of the Progress Report of the Committee of the Sanitary Engineering Division on Filtering Materials for Water and Sewage Works, continued from February, 1930, *Proceedings*.

† Assoc. Prof., San. Eng., Univ. of Kansas; Director and Chf. Engr., Div. of Water and Sewage, Kansas State Board of Health, Lawrence, Kans.

‡ Received by the Secretary, December 19, 1929.

given to the record of the relation between the physical and biological considerations. The Committee has been wise in limiting the field under consideration and developing the data in that field so that it will have practical value to the designer, as a standard specification.

The disintegration of filter rock has been one of the uncertain factors in sprinkling filter design. The development of a specified test to measure the resistance of rock to disintegration will make it possible for the designer to predict with more certainty the future behavior of the filter.

Unfortunately, in many places it will not be economically expedient to use the rock that shows best under the specified test, the cost making the adoption of a local material necessary in so far as possible. It would be of value to know safe specifications for rock that might be used in the body of the filter, providing the surface of the filter was covered to some specified depth with a better and more expensive rock. In some cases the less expensive local rock might be used and the filter housed, thus protecting the stone from weathering as well as securing a degree of odor control.

Aside from the question of the soundness of the rock used in a sprinkling filter, there are many other design problems that are of general interest.

The assumption is general that, with few exceptions, a settled sewage is the proper influent to a sprinkling filter; yet it is well known that settled sewage varies widely in its physical and chemical properties. Designers should know how these variations influence the operation of the filter.

If disintegration is properly controlled, the question of the size of rock used in the filter is of interest as related to oxidizing capacity and the control of clogging. If an effluent better than can be secured by plain sedimentation is available for oxidizing filters, it should create an increased interest in the fine-grained biological filters which have a definite although perhaps limited field of usefulness. Indications are that even greater sums of money will be expended in the future than in the past in the construction of sewage treatment works, and it would seem very important that this Committee, or a similar one, serve the Society in furnishing a source of reliable design data, making it available to the many engineers who must depend upon the Society publications for such information.

Dr. Herbert F. Kriege* (by letter).†—Nearly every branch of science needs to do extensive explorational work. Nevertheless, each branch may gain much information and save much time by applying that knowledge gained from kindred scientific groups. It is not surprising therefore that the Committee has accepted the physical and chemical tests which have been used in judging the merits of mineral aggregates employed in other older ways, whether or not these tests are adequate. It is entirely probable that some of these tests may yield nothing of value for judging mineral aggregates in this field, since they may have been designed to determine characteristics practically uncalled for in the new specific use. It is not too much to expect that from the deliberations and researches of the Sanitary Engineering Division may come some new

* In Chg. of Tests, The France Stone Co. Laboratories, Toledo, Ohio.

† Received by the Secretary, December 26, 1929.

methods of test and some enlightening criticism of the older tests as applied to materials for sewage treatment. Since the mineral aggregate industry has been remiss in providing enough information regarding the desirability of certain aggregates in specialized lines, those in that field are more than casually interested to know what the Committee has been able to discover in its investigations.

The report states* that,

"There appear to be three major considerations which may seriously affect the suitability of a trickling filter material * * *, as follows:

"(*a*) Disintegration.
"(*b*) Cementation and Consolidation.
"(*c*) Ability to Unload."

The purpose of the trickle filter medium is to provide a large, well-aerated surface. Hence, size of material, gradation, cleanness, and surface characteristics are properties more peculiarly belonging to the mineral aggregate than is "the ability to unload" which is a property of the bed and is controlled largely by the method of operating the system. These factors have not been included in the Committee's investigation on filtering materials, but rightfully they belong in that problem.

There can be no question of the value of the first factor, durability, as a consideration. The Committee has done well in selecting the method which seems to be most adaptable as a test procedure in determining the durability of mineral aggregates in advance of their use and attempting to establish the reliability and reproducibility of this method. It was a pleasure to co-operate fully with the Committee in this test during 1928. It is a keen disappointment to have learned from a careful perusal of the recently completed co-operative test report that the term "co-operative" was a misnomer, since several of the laboratories seemed to feel themselves providentially set apart to alter the test procedure to such an extent that their results are without much value, and hence are practically lost to the Committee as far as comparative results are concerned.

In the paragraph headed "Types of Disintegration",† some rather interesting and perhaps questionable inferences are made. For example (quoting), "splitting along seams appears to be more prevalent in hard dolomitic limestones than in the softer calcitic varieties". This may be assumed to mean that hardness usually accompanies the dolomitic increase in limestones, which is not necessarily true. Then, it is suggested that the "crumbling" type of disintegation, such as "seems to be mostly confined to the softer varieties of limestones and to the slags"‡ is most serious. This is a questionable suggestion, with at least two obvious considerations mitigating against it: First, the size of particles most effectively closing up the spaces between the original aggregate pieces is just larger than the space between the pieces, and material smaller than this, such as is formed by "crumbling" will pass through sooner or later; second, the chances are good for the smaller material to be carried off

* *Proceedings*, Am. Soc. C. E., September, 1929, Papers and Discussions, p. 1804.
† *Loc. cit.*, p. 1805.
‡ *Loc. cit.*, p. 1806.

in the drains. The Committee reports finding some of the finer limestone particles produced by disintegration of the filter medium in the outlets from the beds at Mason City, Iowa, and Fort Sheridan, Ill. Further, the Committee's fear that the crumbling of aggregate will lead to consolidation appears groundless. There are very few reported cases of consolidation of the aggregates in a trickle bed. Those that are known have been traced to excessive quantities of fine material produced and concentrated by improper handling and placing of the aggregate in the bed. Recently, it seemed justifiable to make the following statement:* "It is doubtful if cementation ever results from the accumulation of fine material broken down from grosser pieces by disintegration" (under trickle bed conditions). The facts gained since then by the investigations of others and by personal observation, amply substantiate this statement.

It seems rather odd that engineers have not yet learned definitely what types of disintegration (if any) occur to impair the utility of reasonably satisfactory materials. It should be within the province of this Committee to define clearly what kind of disintegration is most serious to the functioning of a trickle bed based on fact. It would not be especially difficult to impose upon some properly functioning filter in isolated areas several sizes of material, such as might result from disintegration, and then note the injury produced on the operation of the bed.

The Committee suggests† that freezing and thawing tests to determine the durability of aggregate might be better than the sodium sulfate method, since it more nearly simulates the conditions in the field. Practically all the freezing and thawing methods thus far devised impose conditions that are far from natural. However, no serious problem confronts the investigator who wishes to reproduce what takes place in the trickle bed. A device to sprinkle thawing sewage or other solution upon frozen aggregate can be made without great difficulty.

Regarding "Cementation and Consolidation",† very little need be said, except that these are not factors of enough importance to warrant the time and attention of the Committee. Stone or slag which is properly sized for trickle-filter use and is not improperly handled or placed in the filter, will not consolidate or cement. It is like arguing about last week's weather to consider what cementation might have occurred on some cinder bed or other material which no competent sanitary engineer of to-day would permit to be used in any case.

Since the Committee's work, the report‡ of another sanitary engineer, C. C. Hommon, Assoc. M. Am. Soc. C. E., now in charge of the Canton, Ohio, sewage plant, has been received. After careful observation of about fifty plants, he states that the ability to unload is not determined by the kind of aggregate, but by the plant practices in vogue. Clogging was found on all kinds of aggregates, but he has shown that it is possible to make dirty beds unload,

* "Mineral Aggregates for Sewage Disposal and for Railroad Ballast," H. F. Kriege, p. 109, Mineral Aggregates Symposium, Am. Soc. for Testing Materials, 1929.

† *Proceedings*, Am. Soc. C. E., September, 1929, Papers and Discussions, p. 1806.

‡ "Report of Investigation of Crushed Blast Furnace Slag as a Medium in Sewage Trickling Filters," C. C. Hommon, National Slag Assoc., 1929.

regardless of the type of aggregate in these beds. It seems logical, therefore, that this later work will aid the Committee tremendously in its thinking along the lines of the unloading ability of trickle beds.

In general, the Committee's work in arranging for the collection and testing of the aggregates from the twenty plants is to be highly commended. The plan of taking, from each bed, some material which apparently had suffered and some which had not, is fine. Any information regarding the effect of years of service upon the future resistance of the material to further service or soundness tests will certainly be of value.

Some of the less pleasing features of the Committee's report are:

(1) The descriptive discussion of each plant sampled is very good reading and contains valuable information. Because of the fullness of each, and the difficulty of avoiding repetition in describing similar installations, much of the value is lost. Tabulations of the major features of the trickle beds and the results of tests made on their aggregates would be most helpful in this comparative study of filter materials.

(2) If the abrasion tests were desired they should have been run according to accepted procedures so that they might have been of some value in comparison with others.

(3) Either some mistaken plan or a mistake in reporting the abrasion losses has crept in, for the values of the fines are here given as based on material less than 1 in. in size; which means—what? The standard procedures consider the material lost which passes ¼-in. openings.

(4) Some of the terms used to define various effects of immersion in Na_2SO_4 are not clear or definite. Thus, "surface abrasion" is mentioned frequently. Is not surface scaling or disintegration more correctly descriptive? Also, certain materials "seemed to have a slight tendency" to do thus or so. A more definite stand is advisable since either these materials did or did not register signs of disintegration.

Since most of the descriptive discussions of the individual plants sampled have some item challenging attention, they will be taken up separately.

It is stated* that disintegration is not noticeable on the surface of the Baltimore, Md., bed. Certainly this aggregate has evidenced remarkable resistance to disintegration, but in 1927 the writer experienced no difficulty in finding pieces on the surface of this bed that had cracked and split.

Under "Decatur, Ill." the first reference is made† to an abrasion test in which the percentage of wear is based upon material reduced to less than the 1-in. size. Since it is standard practice to consider lost that material passing a ¼-in. screen, the result found (2.86%) is of questionable value. If it could be accepted as correct, it would represent a decidedly resistant limestone rather than one "within reasonable limits". It is difficult to follow the Committee's thought in calling "surface abrasion" one of the effects of the sulfate test. Abrading action hardly belongs in this test.

Concerning the plant at Fitchburg, Mass., the conclusion‡ that perhaps the twenty-cycle sodium sulfate test is too severe because one piece of trap-

* *Proceedings*, Am. Soc. C. E., September, 1929, Papers and Discussions, p. 1814.
† *Loc. cit.*, p. 1815.
‡ *Loc. cit.*, p. 1816.

rock out of the ten broke into three pieces, does not seem justified. The twelve New England winters through which the material passed can be expected to lessen the resistance of trap-rock or granite appreciably. Trap-rock frequently does not pass the soundness test perfectly although it is almost always satisfactory. This is found to be true in most cases reported herein and elsewhere.

It is easy to agree with the conclusion,* under "Gloversville, N. Y.", that "any material which will withstand twenty cycles of the sodium sulfate test should be considered satisfactory". Many beds can be cited in which the material will not stand this test and yet serve satisfactorily, while beds containing material for which the reverse is true have not been reported, to the writer's knowledge.

The statement from the conclusions,† under "Rochester, N. Y.", that possibly "all flints and cherts do not behave the same" is very true. Flints and cherts behave very differently, and in fact the present nomenclature permits cherts themselves to differ widely in their soundness behavior. These matters were considered in detail more recently‡ elsewhere.

The Columbus, Ohio, bed is one worthy of full discussion. Although the aggregate has shown disintegration of every form and to an extent that would alarm most engineers,§ the bed continues to function satisfactorily after more than twenty years despite the great overloading (about 50%) of its capacity. Is it not possible that sanitary engineers have gone to the extreme with their demand for great durability of aggregate when one of the largest and oldest beds continues to give good service even though considerable disintegration has taken place and overloading is the general condition? If "on the whole, the material may be regarded as being only partly satisfactory,"§ how much better can "satisfactory" be?

Some misunderstanding must exist regarding the composition of the dolomite from the Fort Sheridan, Ill., trickle bed, or the analysis given is in error. The chemical analysis given in Table 2‖ shows this stone to contain 53.12% $CaCO_3$ and 41.15% $MgCO_3$. It is stated¶ that "the magnesium appears slightly in excess of that required for a true dolomite, suggesting the presence of some magnesite which may account for the chalky appearance". If the analysis given is correct, this sample is deficient in $MgCO_3$ as compared with a true dolomite which has a ratio, $\frac{CaCO_3}{MgCO_3}$, of about 1.188. It is a rare case indeed in which the $MgCO_3$ content exceeds that of true dolomite in the dolomitic limestones of the Central States. Concerning the disintegration and the possible compacting of the aggregate, the information¶ given by the Committee ends with "it is stated that there are signs to indicate that the material in the bed is compacting together or is crumbling down because the surface of the material is constantly lowering." Certainly, readers should

* *Proceedings*, Am. Soc. C. E., September, 1929, Papers and Discussions, p. 1817.
† *Loc. cit.*, p. 1821.
‡ "The Stability of Chert," by H. F. Kriege, *Rock Products*, Vol. 32, 1929, pp. 50–53.
§ *Proceedings*, Am. Soc. C. E., September, 1929, Papers and Discussions, p. 1821.
‖ *Loc. cit.*, p. 1813.
¶ *Loc. cit.*, p. 1823.

have more definite facts in this case, which is very pertinent to the question of "what price permanency?" The abrasion sample of the Fort Sheridan stone contained 157 pieces.* It is very difficult to interpret the results obtained from a test of that kind.

On the Mason City, Iowa, bed it was found that "in many cases the rock appeared to be shot through with seams of sandstone."† Such a combination, particularly in a dense stone, invites trouble; so it is no surprise to find the material disintegrating in test and in service.

A debatable statement‡ appears in regard to the Pontiac, Mich., bed, as follows: "On the whole, this material may be regarded as satisfactory, the disintegration being confined to a relatively small part of the material, and that mostly on the surface." While the soundness test samples did not represent quantitatively the aggregate in the bed, their loss of 24.6% was among the highest found by the Committee. Since a gravel deposit usually contains all kinds of material, the occurrence of unsound pieces may be expected in almost any gravel sample. Furthermore, the reduced voidage and smooth surfaces of rounded aggregate mitigate against the prime purpose of the trickle filter medium, which is to provide a large, well-aerated surface. It would seem, therefore, that the reduced voidage caused by poor sizing (1 in. to 4 in.), round surfaces, and disintegration would cause this aggregate to clog. Such was the case when the writer examined it in the late fall of 1928. Of a dozen beds whose degree of dirtiness was determined quantitatively, the Pontiac bed was found to be the worst.

Considerable discussion has centered about the four trickle beds at Reading, Pa., where slag and feldspar are the aggregates.§ It is interesting to note that the Committee found some soundness test failure in the slag from the older beds, Nos. 1 and 4, which have had 17 and 20 years service, respectively. After 13 years service, the slag in Bed No. 3 passed through without much effect. The same beds sampled by Mr. Hommon‖ and tested by Mr. Fred Hubbard, of Youngstown, Ohio, passed through the tests successfully in all cases. It would have been of interest had the Committee included the feldspar in its tests since this material showed some signs of weathering.

The "Interpretation of Results"¶ reveals the difficulties the Committee encountered in trying to correlate such physical factors as absorption, specific gravity, and abrasion with the ability of the material to resist disintegration in practice or in the soundness test. The hundreds of stone, slag, and gravel samples which have been run for soundness as well as for other properties in the France Stone Company Laboratory have convinced the writer that the ability to resist disintegration is a characteristic apart from the usual physical tests of hardness, toughness, abrasion loss, absorption, etc. This fact will come as a surprise to some sanitary engineers who have long cherished a preconceived and perhaps inherited notion along this line. To illustrate,

* *Proceedings*, Am. Soc. C. E., September, 1929, Papers and Discussions, p. 1823.

† *Loc. cit.*, p. 1825.

‡ *Loc. cit.*, p. 1827.

§ *Loc. cit.*, p. 1828.

‖ "Report of Investigation of Crushed Blast Furnace Slag as a Medium in Sewage Trickling Filters," by C. C. Hommon, National Slag Assoc., 1929.

¶ *Proceedings*, Am. Soc. C. E., September, 1929, Papers and Discussions, p. 1832.

the new Akron, Ohio, installation which should be an example of perfection, represents to the writer, as an investigator in mineral aggregates, just about the way a trickle bed medium should not be. Improper sizing and entirely too much disintegration were in evidence before the bed was put into service.

The chemical analysis was shown by the Committee to be of no definite aid in predicting the durability of material. This in general coincides with the writer's experience, although within the same quarry there is a rather pronounced relationship between the non-carbonate content (silica, alumina, iron oxide, etc.) and the tendency to disintegrate.

Some attempt is made to specify the iron and sulfur content limits in blast-furnace slag. Nothing presented in this investigation warrants that step as the information is entirely inadequate. With a much fuller study of this matter, Mr. Hommon* found that wide ranges in these constituents had no observable effect on the behavior of slags in service or in test.

The important discovery of the Committee's investigation is that the resistances of aggregates to the sodium sulfate soundness tests parallel their ability to withstand actual service conditions. Any one who knows what labors attend such experimental efforts must feel grateful to the Committee. If the foregoing remarks have proved critical, it is because a critical discussion is the best contribution a reviewer can make in order to help avoid the loss of facts acquired and to prevent misinterpretations.

* "Report of Investigation of Crushed Blast Furnace Slag as a Medium in Sewage Trickling Filters," by C. C. Hommon, Natural Slag Assoc., 1929.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

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GENERAL SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

PREPARED BY COMMITTEES FROM
THE AMERICAN SOCIETY OF CIVIL ENGINEERS
AND
THE AMERICAN RAILWAY ENGINEERING ASSOCIATION

Discussion*

BY MESSRS. M. F. CLEMENTS, BENJAMIN W. GUPPY, R. C. STRACHAN, CHARLES EVAN FOWLER, PAUL A. BLACKWELL, W. H. COURTENAY, R. B. HOUSTON, L. P. DREW, F. P. SHEARWOOD, C. M. GOODRICH, WILLIAM MICHEL, H. A. GERST, H. AUSTILL, AND B. A. WOOD.

M. F. CLEMENTS,† M. AM. SOC. C. E. (by letter).‡—The design of railroad bridges is in the hands of the railroad bridge engineers who have supported the work of the American Railway Engineering Association. Approximately 90% of the railroad mileage of the United States now can be listed with companies that have its bridges designed according to the existing specifications of that organization. It is only by joining with that organization in formulating a specification that the Society can hope to present one that will come into general use. With the backing of the two organizations working together it is possible that the A. R. E. A. specification may be supplanted.

The proposed specification has the fault common to all new specifications in that it proposes a new typical wheel diagram to supplant the Cooper loadings. Why change the wheel arrangement? The one proposed (Fig. 2§) is no more nearly standard than the Cooper loading. It is out of date before it is adopted. Why not eliminate it entirely in favor of the uniform loading?

* This discussion (on General Specifications for Steel Railway Bridges, published in December, 1929, *Proceedings*, but not presented at any meeting of the Society) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Bridge Engr., N. P. Ry., St. Paul, Minn.

‡ Received by the Secretary, December 5, 1929.

§ *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2651.

There is no existing locomotive like Fig. 2, and there never will be. The present tendency in locomotive design is toward large, heavy tenders to take care of long engine runs, and the tenders are designed to the maximum that the rail will bear. If the wheel loads of the tenders are increased to make them equal to the driver loads, it will more nearly approximate a modern locomotive. Why not give all wheel loads the same value and then discard the whole diagram for a uniform load?

BENJAMIN W. GUPPY,* M. AM. SOC. C. E. (by letter).†—Referring to Articles 203‡ and 204‡ of the specifications, the writer believes that the almost universal practice of reducing live load on a multiple-track bridge is due to the fact that such a bridge does not receive its maximum loading as frequently as a single-track bridge. As density of traffic increases, the probability of a multiple-track bridge receiving its full live load also increases. The writer has noted on several occasions a three-track, two-truss bridge with maximum engines on two tracks and a train of loaded coal cars at rest on the third.

Assuming tracks at 13 ft. 0 in. from center to center and the distance from center of track to center of girder as 9 ft. 0 in., let L = full live load on one track; then the reduction in live load as determined by the new specifications are given in Table 7.

TABLE 7.—PERCENTAGE REDUCTION OF LIVE LOAD AS DETERMINED BY NEW SPECIFICATIONS.

Number of tracks.	Number of girders.	Maximum Live Load on One Girder.		Percentage of reduction of live load.
		Full live load each track.	Live load according to new specification.	
2	2	L	L	0
3	2	$1.5\,L$	$1.479\,L$	1.4
4	2	$2.0\,L$	$1.947\,L$	2.7
4	3	$2.0\,L$	$1.942\,L$	2.9

These small percentage reductions of live load will result in a saving of metal in the girders of only a fraction of 1% and, considering the uncertainty regarding the future use and maintenance of the bridge, the small reduction seems like an unnecessary refinement.

The writer believes that the proper place to make a reduction in the loading on multiple-track bridges is in the impact allowance and not in the track load. Furthermore, the proper form for an impact formula is one that takes account of the loaded length of track producing maximum stress in a member, and the ratio between live and dead loads. Surely some reduction in impact should be made in the girders of a bridge having a heavy ballasted deck. The impact reduction proposed in the specifications gives some sur-

* Engr. of Structures, B. & M. R. R., East Cambridge, Mass.

† Received by the Secretary, December 18, 1929.

‡ *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, pp. 2651-2652.

prising results. For example, using the same values for spacing of tracks and girders as before, then, for a double-track bridge with two girders, the maximum load on one girder is L and the impact on that girder is $0.71\,L$, and, for a double-track bridge with three girders, the maximum live load on the inter-track girder is also L, but the impact is only $0.50\,L$.

In other words, on two girders of the same span and with the same live load there is a variation of 42% in the impact allowance. Is this difference justified by any experiments? If the two designs call for any variation in the impact allowance, the writer believes that the three-girder case should have the greater allowance because the single-track floors will ordinarily have less weight to absorb shock than the double-track floor. Is the additional load of 20 000 lb. stipulated in Article 209* a constant, irrespective of the number of tracks?

R. C. STRACHAN,† M. AM. SOC. C. E. (by letter).‡—In the preparation of a report such as this, which represents most careful work on the part of leading members of the Profession, it is naturally to be expected that differences of opinion have developed, and that some of the provisions embodied in the published report are compromises which may be straightened out through general discussion. It appears probable that Article 419§ is in that category.

The proposed formulas for the shearing force, R, assumed to produce stresses in lattice-bars, are based on an analysis of the effect of a hypothetical lateral force causing hypothetical reactions at the ends of the member. The solution of two rather formidable expressions containing the factor, I, must be completed before the hypothetical stresses in the bars can be calculated for one member.

The same theory leads to the expression adopted in the 1923 specifications. As compared with the Committees' new formulas, the earlier one has the advantage of greater simplicity and its results, judged by the finished member, are likely to be quite as satisfactory, provided the theory of the hypothetical force is accepted. Equally good design could be attained, however, by specifying simply that R shall be taken on the basis of tests at a certain percentage of P, thus removing the deceptive impression of scientific accuracy conveyed by Equations (1) and (2) in Article 419.

CHARLES EVAN FOWLER,‖ M. AM. SOC. C. E. (by letter).¶—The writer is naturally very much pleased to know that the movement he instituted about 1920, has reached the contemplated fruition of a Standard Specification for Railway Bridges in co-operation with the American Railway Engineering Association. There is, however, much regret expressed by many who are vitally affected by such a standard, that the document is needlessly specific, that more complicated formulas and procedure have been adopted, and that

* *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2653.
† Cons. Engr., N. Y.
‡ Received by the Secretary, December 20, 1929.
§ *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2657.
‖ Cons. Engr., New York, N. Y.
¶ Received by the Secretary, December 20, 1929.

the design, fabrication, and erection of structures have been so hopelessly interwoven in one document.

Time will undoubtedly cause a great simplification, if that is not accomplished before the final adoption. The dropping of the straight-line column formula, is, in a measure, a step backward, even if the Gordon formula is more nearly correct. The straight-line formula was accurate enough for all practical purposes, and was very easy to remember and apply without access to tables of values. Various other things should be corrected now, instead of awaiting another decade for modifications to occur by evolution. The writer also believes that the loading should be a future maximum, such as would be represented by E-90, or a comprehensive curve, and that then the unit stresses should be adopted at the elastic limit of the steel.

The specifications could well be printed in four parts: Design; material; fabrication; and erection. Care should be taken to see that the specification does not cover clauses that properly belong in a contract; if such clauses are included, they should be so segregated as to be readily eliminated or changed as required by the needs of the contractor.

After all, with the mystery of detail bridge design fully exploded, it becomes a mere practical matter for an agreement by all the parties concerned in the design and building of a bridge. Therefore, why not go a step farther than the writer originally had in mind, and ask the fabricators for their opinion, as based on experience. When such a sweeping agreement has been consummated, all the difficulties will have disappeared and bridge design and construction can proceed year in and year out, like the operation of a well designed and well oiled piece of machinery. In the writer's humble opinion there is entirely too much being left to be smoothed out during future years of more or less notable conflict.

PAUL A. BLACKWELL*, M. AM. SOC. C. E. (by letter).†—The Joint Committee of the Society and the American Railway Engineering Association has presented in this report a very complete specification, which represents a great deal of hard work. The adoption of a single specification for railway bridges by all railways in America is of such importance that these specifications should be discussed very thoroughly.

The following criticisms and suggestions referring to specific articles‡ in the report are meant to be constructive.

Article 5.—A better wording would be as follows: "Ordering of material by the Contractor prior to approval of the stress sheet shall be at his own risk."

Article 109.—The writer suggests that this should read: "In skew bridges the ends of support for each track preferably shall be square with the line of track."

Article 203.—Live Loading.—The majority of bridges in the United States are less than 65 ft. in span. Probably about 60 ft. would be the length of the average bridge. A comparison of such a girder bridge designed for the

* Chf. Engr., Virginia Bridge & Iron Co., Roanoke, Va.

† Received by the Secretary, December 23, 1929.

‡ *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, pp. 2649 *et seq.*

A-64 loading and the proposed specification and an E-64 loading and the A. R. E. A. 1925 specifications results in about 11% more weight for the A-64 loading.

The M-60 loading of the A. S. C. E. 1923 specifications* will result in a bridge about 8% heavier than the recommended A-64. Inasmuch as the E-type of loading gives bridges too heavy for long spans and too light for short ones, the writer suggests that the M-60 loading be adopted, and inasmuch as very few bridges are now built for a uniform live load, the alternate loading may be omitted.

Article 204.—Impact.—There seems to be no reason for this revision because for a 100-ft. span it will give the same impact as the A. R. E. A. 1925 formula. The proposed formula with M-60 loading would probably work out economically. The proposed specification is too complex in stating how this impact should be applied. A simple statement that l in the formula is the loaded length of all tracks, comes nearer the actual conditions and gives economical results.

Articles 205 to 210, Inclusive.—The writer could never see the logic of applying centrifugal force 6 ft. above the top of the rail when the only way it can get to the bridge is from the wheels of the train at the top of the high rail. For the same reason, why should the wind on the train, taken at 300 lb., not be applied at the top of the rail? The sway of the engine (Article 209) specified at 20 000 lb. applied at the base of the rail, is purely empirical; a percentage of the uniform load and its application at the top of the rail is as logical for this force and as easy to apply as any specified load. The question of longitudinal force (Article 210) 20% of the load between expansion points, applied at the top of the rail, is more in conformity with actual conditions than that specified.

Article 211.—This Article should be amplified by stating how the connections are to be made as it is customary to make them good for the sum of the tension and compressive stresses without the 50% increase. This point should be made clear.

Article 300.—It is somewhat startling to note, after about twenty-five years' disuse, that a unit stress for dead load can be taken 50% greater than for live load. As the writer understands it a load, regardless of its character, is to be taken care of by so many square inches of steel, and to use a different unit stress for dead load and live load not only complicates the designing and detailing, but is not keeping up with progress.

Article 301.—Unit Stresses.—The writer prefers the straight-line compression formula instead of the parabolic formula.

Article 401.—The minimum thickness of material should be $\frac{3}{8}$ in. and the minimum angle, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{3}{8}$ in., with three rivets. This will eliminate the thickness specified for gussets. Whether or not the material is subject to corrosive influence should be called to the attention of the manufacturer when inquiry for prices is made.

Article 408.—This whole section is too complicated; the A. R. E. A. specifications will give the same results and are much easier to use.

* *Transactions*, Am. Soc. C. E., Vol. LXXXVI (1923), p. 477.

Article 419.—Either Equation (1) or Equation (2) should be given; not both.

Article 421.—The last sentence should be made clearer by rewording as follows: "Lattice-bars connecting to flanges 5 in. and more wide shall have two rivets in each end."

Article 428.—The writer can see no advantage in running the first bottom cover plate the full length on a plate-girder bridge; nor can he see any necessity for two lines of rivets in the outstanding legs of plate girders with 6-in. angles.

Article 433.—The formula for spacing of stiffeners is too complicated and should be simplified.

Article 434.—It will be very difficult indeed, without increasing the width of through-plate girders of considerable depth, to make the floor-beam bracket extend to the top of the main girders. This Article should be revised to read that "the brackets shall extend up as far as possible toward the top of the main girders".

Article 435.—Tower spans on viaducts should have bottom laterals.

Article 439.—The writer would like to have the term "short" bent defined.

Article 443.—This Article should be revised to read: "Spans more than 80 ft. (out to out) shall have pin-bearings, and shall have rollers at one end."

Article 445.—Omit the last sentence, as this will be taken care of in Article 443 and include the sentence, "pedestals may be built up of plates welded together."

Article 448.—This Article is too indefinite as regards camber. It should be revised to read: "In spans of 200 ft. or less, provision shall be made for camber by increasing the top chord $\frac{1}{8}$ in. in each 10 ft. Spans more than 200 ft. long shall be cambered by changing the length of individual members so that the bridge will be level under dead and live load."

Article 503.—This statement appears in nearly all specifications. It causes increased fabrication cost, is of doubtful value, and the same result could be achieved by making the minimum edge distance for rivets $1\frac{3}{4}$ in. instead of $1\frac{1}{2}$ in.

Article 504.—This specification is very difficult to interpret; it should make clear that holes shall be punched full size, or sub-punched and reamed.

Article 509.—"Reaming and drilling shall be done with twist drills." This Article should be eliminated because there is too much chance for an argument with the Inspector and if necessary to ream, it should state that regular straight or spiral-fluted bridge reamers shall be used.

Article 515.—This is very indefinite; it would be much better to say "standard shape" and give some specific standard.

Article 535.—Why must pins 9 in. or more in diameter have a 2-in. hole bored longitudinally through the center? This is very expensive operation.

Article 537.—The first sentence of this Article should be eliminated as it is always necessary that screw-threads fit the nut-threads and they would be so made in any first-class bridge shop.

Article 540.—This Article undoubtedly applies to pin-connected spans only, but it should be so stated.

Article 541.—This could be condensed considerably by simply saying "thoroughly cleaned".

Article 602.—This Article should specify that if full tests are required, the Engineer should so stipulate in his inquiry.

Article 701.—If "1½%" is changed to "2½%" Articles 701 and 702 will agree.

Articles 801 to 1201, Inclusive.—Sections 8, 9, 10, 11, and 12 could be done away with entirely by simply calling for material to be rolled to the A. S. T. M. specifications and giving the serial number for each class of material. This would condense the specifications, save time at the mills and the fabricating shop, and would result in just as good material.

W. H. COURTENAY,* M. AM. SOC. C. E. (by letter).†—Referring to Article 300,‡ it does not seem advisable to have the dead load "proportioned for unit stresses 50% greater than those allowed in Article 301," or 24 000 lb. per sq. in. for railroad spans of moderate length.

Notwithstanding all the care taken to keep bridges properly protected from rust by painting at frequent intervals, they do rust and lose section thereby. Practice on the Louisville and Nashville Railroad has been to design for a unit stress of 16 000 lb. for both dead and live load.

Article 442§ states in part: "In spans more than 400 ft. long, provision shall be made for expansion in the floor". The Louisville and Nashville Railroad Company has found by bitter experience that on spans less than 400 ft. long, in which the track stringers are connected to webs of floor-beams by hitch angles, the hitch angles break. Its practice has been in recent construction of spans longer than 200 ft. to provide double floor-beams so as to break the continuity of the track stringers. On some spans the Company had to replace broken hitch angles connecting floor-beams to track stringers more than once. It would seem, therefore, to be advisable to change the sentence in Article 442 to read: "In spans more than 200 ft. long provision shall be made for expansion in the floor."

The first part of Article 504‖ seems to indicate that whenever the thickness of the metal is greater than ¾ in. for structural steel the rivet holes may be punched without later reaming. This does not appear to be good practice. Punching the metal is liable to start incipient cracks which are not visible on inspection, but which may develop later. The metal for all members should be sub-punched and later reamed, except for lateral braces.

R. B. HOUSTON,¶ ASSOC. M. AM. SOC. C. E. (by letter).**—The writer questions the use of Formula (2), under Article 419†† on proportioning of lattic-

* Chf. Engr., Louisville & Nashville R. R., Louisville, Ky.

† Received by the Secretary, December 26, 1929.

‡ *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2653.

§ *Loc. cit.*, p. 2661.

‖ *Loc. cit.*, p. 2662.

¶ Chf. Draftsman, Kansas City Structural Steel Co., Kansas City, Mo.

** Received by the Secretary, December 26, 1929.

†† *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2657.

ing, because Formula (1) seems to give the larger value, for structural steel, in all cases. For a value of 10 000 lb. for p, Formula (1) gives:

$$R = 40\,000 \left(\frac{I}{C\,L}\right)$$

and Formula (2) gives,

$$R = 40\,000 \left(\frac{I}{C\,L}\right)$$

For a value of p equal to 13 500 lb. (the maximum) in structural steel, Formula (1) would give a value for R approximately five times as large as Formula (2). The latter would give the larger result when p is 18 182 lb., or more, which could only occur with high strength steels; but members would require much lighter latticing than the same section in structural steel stressed to 13 500 lb.

The A. R. E. A. 1929 Specifications for Steel Highway Bridges include the same formulas except that 24 000 lb. is substituted for 20 000 lb. in Formula (1). This, of course, makes Formula (2) still less applicable.

L. P. DREW,* ESQ. (by letter).†—The proposed specifications differ in many details from those in common use, but appear to be an advancement to meet the requirements of modern design. In particular, the writer is favorably impressed with the new type of live load (Article 203)‡; it is decidedly more in keeping with the trend of modern design in locomotives than the old Cooper loading which has been used heretofore.

The writer is very much in favor of a general specification for railway bridges being adopted by both the American Railway Engineering Association and the Society, as this will tend to standardize construction throughout the United States and make it possible for interested companies to secure better prices, quicker delivery, and more uniform structures than was possible under the old arrangement of different specifications for different lines or locations.

F. P. SHEARWOOD,§ M. AM. SOC. C. E. (by letter).‖—Sections 1, 2, 3, and 4¶ of the proposed specifications cover very completely the designing of steel railway bridges. Perhaps the most severe criticism to be made is that they control the designer too strictly and, for the sake of preventing any one from wilfully cutting into the necessary strength, they restrict the able and honest designer to too narrow lines.

Section 5,** treating with workmanship, differs principally from preceding specifications by omitting reference to reaming and planing of thin material. This is a reasonable concession to those shops which are well equipped with modern machines ensuring accurate punching and assembling; but the writer

* Bridge Engr., Los Angeles & Salt Lake R. R., Union Pacific System, Los Angeles, Calif.
† Received by the Secretary, December 28, 1929.
‡ *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2651.
§ Chf. Engr., Dominion Bridge Co., Ltd., Montreal, Que., Canada.
‖ Received by the Secretary, December 21, 1929.
¶ *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, pp. 2649-2661, inclusive.
** *Loc. cit.*, pp. 2661–2665.

believes that there should be some standard of accuracy specified for the matching of holes, so that sub-punching and reaming is automatically called for when unusual make-up of members or inefficient fabricating equipment is likely to produce unfair holes.

The omission of any reference to burning or welding should be corrected, as all shops are using these methods very extensively.

High-Tension Steel.—To increase the unit stress in direct proportion to the yield point is hardly justified, especially if the ultimate strength is not correspondingly increased, and the elongation diminished. Increasing the unit stress while the modulus of elasticity is not increased must mean added distortion and, therefore, increased secondary strains. All or most of the high-tension steels are more brittle, give more trouble and anxiety in fabrication, and are far more likely to develop minute cracks from punching, shearing, or straightening. These dangers have been recognized in the Articles for punching and shearing (Articles 503* and 504*). Silicon steel also has the disadvantage of not always being quite uniform in hardness, and it is certainly less ductile than ordinary structural steel. All these facts increase the possibility of faults and failure with the use of higher tension steel as compared with the more workable structural steel, and should either warrant the use of a higher factor of safety for silicon and other high-tension steels, or a lower factor for structural steel.

Article 107† is evidently intended to prohibit multiple systems of web bracing and continuous span construction. Practical experience has often shown that double systems of bracing and other indeterminable resistances are a source of safety, especially in the case where accidents have occurred and the span has been saved from absolute failure by a double system or by the secondary strength of the members. Continuous spans have many advantages especially in reducing deflections and by loading the piers more symmetrically. It does not seem justifiable to discourage possible improvement for the sake of gaining mere theoretical determinacy.

Article 106† conflicts with Article 212.‡ If the bending moment in the floor-beam is relieved by the stiffness of the posts, why not specify that the floor-beam and its connections be calculated accordingly? In other words, it is inconsistent to state in one Article that the floor-beams are to be calculated as simple spans between centers of trusses, that is, with no moment at the trusses, and in another Article that they are to be calculated with the moment at the same point.

Article 404§ prohibits cover-plates less than one-fortieth of the greatest distance between adjacent rivet lines, and may encourage designers to use lacing instead of cover-plates. There is no reason why a cover-plate need be any thicker than the stay-plates (which are limited to one-fiftieth), provided they are not counted on to resist compression at too high a unit stress.

* *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2662.
† *Loc. cit.*, p. 2650.
‡ *Loc. cit.*, p. 2653.
§ *Loc. cit.*, p. 2655.

Article 415* outlines what appears to be rather too rough a method of providing compensation for the bending in the rivets on account of intervening plates. It is extravagant for thin plates and inadequate for thick ones. It also takes no account of the gauges of the rivet lines. The number of rivets beyond the splice should be in some ratio to the stress to be transferred.

The first formula in Article 419*, which is evidently based on the assumed flexural stress in the member, will govern in most cases, because Equation (2) will only be effective when the unit stress is very high (about 18 200 lb.). It would be interesting to know the theory on which Equation (2) is based. In Equation (1) the 20 000 should vary according to the different strengths of steel to be used.

It is difficult to understand why very heavy flange angles (Article 428)† are preferable to lighter ones with cover-plates, except to save shop costs or to avoid spotting for rivet heads in deck girders. Flange plates on plate girders must add lateral stiffness to the flanges and, therefore, should not be discouraged.

To specify that one bottom cover-plate must run the full length seems unnecessary and, in many cases, this would be quite wasteful.

The result of adopting Article 433† would be a very extravagant use of stiffeners, and it does not seem to be justified since there is so much evidence of old plate girders with few or no stiffeners having withstood extreme overloading satisfactorily.

Referring to Article 439‡, there is no more reason for specifying intermediate struts in towers with a double system of bracing than for using similar verticals with the lattice system of a compression member. Moreover, these so-called struts must really be ties, because they will act in tension and not in compression until the diagonals have been stressed beyond their resistance as compression members.

The omission of a clause in Article 501§ to require painting contact surfaces is certainly an improvement. Such omission will ensure better friction and tight rivets in the joints; it will make the assembling shop cleaner, and, in this way, will tend to improve workmanship.

C. M. GOODRICH,‖ ESQ. (by letter).¶—A paragraph outlining the limits of the application of these specifications should appear at the beginning.

*Article 204.***—The writer believes that, at least in four-track bridges, impact is probably taken too low, although this is fashionable. Aside from this, however, the entire Article is worded in a way that lacks adequate clearness; it should be rewritten to make clear the intention (if such it is) that S in all cases should be the maximum computed live-load stress in the truss or girder, resulting from the loading of a single track. The sentence "for

* *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2657.
† *Loc. cit.*, p. 2659.
‡ *Loc. cit.*, p. 2660.
§ *Loc. cit.*, p. 2661.
‖ Chf. Engr., The Canadian Bridge Co., Ltd., Walkerville, Ont., Canada.
¶ Received by the Secretary, December 30, 1929.
** *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2652.

girders and trusses of double-track bridges, the impact shall be taken from the full live load on the track nearest the girder or truss" allows a different interpretation, as do other parts of the wording. The length, *l*, in feet of span is defined so as to allow two interpretations: First, the loaded length; and, second, the length of span of the truss or girder under computation.

*Article 209.**—Apparently, the intention here is to specify a lateral force, the effect of which shall be considered only in connection with the horizontal lateral system in the plane of the loaded chord, and in the case of deck bridges in connection with the sway system at the ends of such structures. This Article admits this interpretation, but lacks definiteness.

*Article 211.**—There should be preferably a cross-reference to Article 302.† The writer has always believed that the floor system complete, with such members as carry it, and the web members, should also be proportioned for a single-headed train with a weight of engine, say, 50% greater than that of the engine used in the double-headed train specified. The resulting stresses should be cared for at the normal unit stresses.

Article 301 (b).‡—The specifications allow 27 500 lb. as a minimum yield point, and it would be improper to increase working stresses in what is usually known as silicon steel in proportion to the ratio 45 000 : 27 500. This is here allowed, but 50% is ample in most cases, and 40% is enough, at present and until more experience is had, for railway structures. In connection with the rivets, no clear statement is made as to increases in stresses if higher carbon rivets are used; at present, steel rivets with high ultimate strength are being used on at least one railroad in Canada, and on the Kill van Kull Bridge, manganese rivets of considerably higher strength than usual, are being used.

Article 409.§—In the first sentence in the first phrase, reference is made to angles on one side of gusset-plates, while the second part of the sentence refers to unconnected legs, thus joining two unrelated ideas. In the second sentence the conditional clause is theoretically impossible in a stressed member. It should be noted in connection with Article 409, that the length of the connection has much to do with the value of an angle connection, although specifications usually ignore this fact.

Article 428.‖—The "theoretical point" mentioned is usually taken from a parabola which is incorrect. As German engineers have shown from time to time, practical correctness is obtained if the parabola is cut in two and about one-half the 5 ft. which separates two consecutive drivers is added to it. From a practical standpoint it is usually safe to add 4 ft. to the technical length as determined from the parabola; 2 ft. is usually not enough.

Article 434.¶—Top flanges of through plate girders should be braced to carry some definite proportion (between 2% and 3½%) of the axial stress in the top flange at the point of connection; no definite percentage is given in the specification. The last sentence states that "in solid floors these braces shall

* *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2653.
† *Loc. cit.*, p. 2655.
‡ *Loc. cit.*, p. 2654.
§ *Loc. cit.*, p. 2656.
‖ *Loc. cit.*, p. 2659.
¶ *Loc. cit.*, p. 2660.

be not more than 12 ft. apart". This spacing should depend upon the proportions and width of the top chord; it is realized, however, that the clause given, although unwise, has become fashionable.

*Article 439.**—It is noted that the second sentence rules out the plus and minus braced towers without intermediate struts. This agrees with the writer's view of the matter, but the advisability of including the clause is questioned.

Article 443.†—Spans more than 70 ft. long are required to have rollers. This matter should be determined, not by a severe thumb rule, but by the character of the bottom flange or chord; the writer can see no reason why any girder span should not have sliding bearings; stiff trusses should be similarly treated.

Article 503.‡—It is presumed that the planing of sheared edges is intended to refer to tension edges; this is by no means clear in the specifications.

Article 504.‡—The writer suggests that the first sentence be changed to read,

"Material, * * * may be punched $\frac{1}{16}$ in. larger than the nominal diameter of the rivets, whenever the thickness (of the individual pieces of rolled steel) is not greater than $\frac{3}{4}$ in. for structural steel, or $\frac{1}{2}$ in. for alloy steel."

Where the Engineer desires reaming he should have it; the specifications should at least give him the choice.

Article 506.‡—The statement is made that "no interchange of reamed parts will be permitted". This is a long stride backward, and does not agree in spirit with Article 512.‡ When accurate work is done and metal templets are used for reaming, any member should and can replace any members of like mark in a bridge.

Article 528.§—This Article states that, "Where joints are not fixed the opening shall not exceed $\frac{1}{4}$ in." In many cases this is unnecessarily severe, and in the case of a joint between a sloping end post and a bottom chord in a through bridge it is obviously inappropriate.

Article 546.‖—Provision should be made for arbitration under this Article.

The writer trusts that possibly one or two of these suggestions may be found pertinent.

WILLIAM MICHEL,¶ M. AM. SOC. C. E. (by letter).**—It has been the writer's experience from a maintenance viewpoint that material used for portal and top-bracing members (see Article 436††) is never heavy enough by 75 per cent. Such members require frequent renewal due to corrosion, and the writer would recommend that they be made considerably heavier than the ordinary practice would require.

* *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2660.
† *Loc. cit.*, p. 2661.
‡ *Loc. cit.*, p. 2662.
§ *Loc. cit.*, p. 2664.
‖ *Loc. cit.*, p. 2665.
¶ Chf. Engr., The Hocking Valley Ry. and C. H. Ry., Columbus, Ohio.
** Received by the Secretary, January 4, 1930.
†† *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2660.

Nothing is said in Article 444* about rocker bearings, which are very much superior to roller bearings for spans between 70 ft. and 200 ft. (practically no maintenance required).

In Article 522,† concerning lacing-bars, for compression members nothing is said about the use of angles *versus* flat bars. It is conceded that angles are more desirable than flat bars and, unless Article 419‡ takes care of this feature, something should be said about their use.

H. A. GERST,§ ESQ. (by letter).‖—The Committees are to be commended for their work in drafting these comprehensive specifications. The writer would recommend a few minor revisions as follows:

Article 204.¶—*Impact.*—For bridges designed exclusively for electric traction the writer favors specifying one-half the normal (formula) impact, instead of one-third. Further, he considers it consistent to use this reduced impact for the uniform train load following all double-headed engines, that is, for steam locomotives as well as for electric locomotives. In other words, for ordinary rolling loads where no over-balances in the wheels except as in the drivers of steam locomotives, designers should be justified in using one-half the normal impact. Also, consideration should be given to the fact that on some of the ore-carrying lines the average uniform train load equals more than 7 500 lb. per lin. ft. of track, without impact. Of course, the foregoing is of prime importance in the design of long-span bridges.

*Article 301.***—*Unit Stresses.*—Under Paragraph (*c*), dense Douglas fir, in the writer's opinion, should be assigned the value of 1.4, instead of 1.2, because 1 400 lb. per sq. in. is now much in use as a safe permissible working stress.

Article 523.††—*Fit of Stiffeners.*—Rather than reject stiffeners which fail to fit tightly against flange angles, it would be well to recommend as an alternative that fillet-welds be required at such imperfect junctures. This would go far toward making a sound contact and would eliminate corrosion and loss of metal frequently found at just such points, especially at the bearings of end stiffeners on legs of bottom flange angles of girders.

H. AUSTILL,‡‡ M. AM. SOC. C. E. (by letter).§§—The writer's views are in no way intended as a criticism of the work of the Committees, but are simply a statement of ideas that occur to an engineer who has had some years of experience in dealing with maintenance troubles.

The major changes in specifications now in general use are: Change of loading; use of different unit stress for dead and live loads; and change in the impact formula.

* *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2661.
† *Loc. cit.*, p. 2663.
‡ *Loc. cit.*, p. 2657.
§ Asst. Bridge Engr., Lines West, G. N. Ry., Spokane, Wash.
‖ Received by the Secretary, January 13, 1930.
¶ *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2652.
** *Loc. cit.*, p. 2654.
†† *Loc. cit.*, p. 2663.
‡‡ Bridge Engineer, Mobile & Ohio R. R., St. Louis, Mo.
§§ Received by the Secretary, January 17, 1930.

Of course, engineers have sought, for many years, to improve on Cooper's Equivalent Loading and while the writer never saw or heard of an engine that complied with his diagram he has never known of a proposed loading that seemed to suit general conditions quite so well. The proposed loading may approximate some few locomotives in use now, but it is questionable whether it will be any closer to an average of all locomotives in use twenty years from now than that of Cooper. The spacing of drivers has been retained at 5 ft.* How many locomotives with 64 000-lb. axle loads have drivers spaced at 60 in.? The tendency, of course, is always to increase the weight of locomotives, but so far this has necessitated increasing wheel spacing. It is of interest to note that the load per linear foot of the proposed engine is 9 000 lb. while Cooper's E-64 is 9 467 lb. Most railroads have prepared rating diagrams for bridges and engines so as to compare Cooper's loading with others in current use. The writer doubts that the labor of preparing additional rating diagrams for comparisons with the new loading will be justified.

Cooper's loading has been in general use so long that most railroad executives have a fairly clear idea of what it is and unless it is proved to be wasteful or unless it is no longer approximately "equivalent", the writer would oppose discontinuing its use for a new loading unless perhaps more is to be gained than he can now see by using the proposed loading.

Purely as a practical matter, the writer opposes increasing the designing stress for dead load from 16 000 to 24 000 lb. It may be true that it is within the elastic limit, but it allows a decrease in the "safety factor." Few bridges are built that at some time are not allowed to corrode or that are not required to withstand shock or strain for which they were not designed. Furthermore, will the proposed impact formula apply as well to a span designed for a dead load stress of 24 000 lb. as for one designed for 16 000 lb.? Certainly mass absorbs energy of impact to a certain extent and while the proposed formula provides an impact allowance of 35.7% for a 300-ft. span against 25% required by the present A. R. E. A. formula, the subject should be well considered before making a change, and it is doubtful if sufficient information is available to justify the proposed changes at this time.

The specification should be prefaced by a notation and those symbols should be used consistently throughout. In Article 204,† l = length, in feet; in Article 419,‡ l = length, in inches. Furthermore, since all other symbols used in Article 419 are defined, it would seem only consistent to define P and A also.

Article 301(b)§ refers to "High-Tension Steel" and Article 504‖ refers to "Alloy Steel." It would seem advisable to adopt one term and use it throughout the specification after determining a definition for it.

In Article 415‡ two extra lines of rivets are specified for each intervening plate. In Article 427¶ the length of flange plates is required to be such as to

* *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2651.
† *Loc. cit.*, p. 2652.
‡ *Loc. cit.*, p. 2657.
§ *Loc. cit.*, p. 2654.
‖ *Loc. cit.*, p. 2662.
¶ *Loc. cit.*, p. 2658.

allow two rows of rivets of the regular pitch. In these Articles, "lines of rivets" and "rows of rivets" evidently carry the same meaning. Would it not be better to define one as parallel to and the other as transverse to the axis of the member and thus use the terms?

*Article 2.**—The writer suggests that the last sentence should read,

"Invitations requiring the contractor to furnish the design shall state the general conditions at the site, such as * * * character of substructures, * * * etc."

Article 103.†—The following rewording of the first sentence is recommended: "The distance between centers of trusses or girders shall be sufficient to prevent uplift (or 'a negative reaction'), by the specified lateral forces."

Article 105.†—The writer suggests changing two sentences in this Article to read:

"On curved track the clearance shall be increased to allow for the overhang and the tilting of a car, 80 ft. long, 60 ft. between centers of trucks, and 14 ft. high as measured from the top of rail."

Article 302.‡—To avoid confusion this should state definitely whether live load plus 50% plus other stresses shall not exceed the allowable unit stress for dead load or whether live load plus 50% (omitting other stresses) shall not exceed the allowable unit stress for dead load.

Article 401.‡—For practical reasons the writer would oppose using metal less than $\frac{3}{8}$ in. thick except for filters in railroad bridges. Too little margin is afforded as insurance against corrosion when metal $\frac{5}{16}$ in. thick is used.

Article 429.§—Instead of stating that "flange angles shall be spliced with angles", the writer would prefer to say "when flange angles must be spliced, the splice shall be made with angles", or "splices in flange angles shall be made with angles".

Article 433.§—Move the sentence, "if the depth between the flanges is less than fifty times the thickness of the web, intermediate stiffeners may be omitted", to the top of the Article and then start the next sentence "when required, webs of plate girders shall be stiffened, etc."

Article 443.‖—As a practical matter rollers should be required on spans of more than 50 ft. After a bridge has been in service a number of years the friction between sliding bearing plates is likely to increase; furthermore, the expansion slots in the upper plate often become packed with rust or foreign matter and the expansion is taken or resisted by the pier, with a tendency to crack the pier.

Article 445.‖—Since this Article permits the use of cast iron a minimum thickness should be specified for cast iron also.

Article 603.¶—Since the table of working stresses is headed "structural" steel, would it not be well to specify that the figures for eye-bar test are for "structural" steel?

* *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2649.
† *Loc. cit.*, p. 2650.
‡ *Loc. cit.*, p. 2655.
§ *Loc. cit.*, p. 2659.
‖ *Loc. cit.*, p. 2661.
¶ *Loc. cit.*, p. 2665.

*Article 607.**—Since some contracts include the erection of a bridge for a single stated pound price it would seem best to state clearly that the price to be paid for tested bars is the shop or fabricated price.

*Article 701.**—This Article should state that the pound price does or does not include shop paint.

B. A. Wood,† Esq. (by letter).‡—The writer is interested especially in the minimum live load for each track as recommended by the Committee in Article 203.§ This loading seems to be equivalent to the maximum now in use. It is the writer's opinion that the Cooper E-60 minimum is sufficient for the present-day railway loading. Certainly, it is for all except extreme cases, for which suitable provision may be made to take care of special conditions.

* *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2666.
† Chf. Engr., Mobile & Ohio R. R., St. Louis, Mo.
‡ Received by the Secretary, January 31, 1930.
§ *Proceedings*, Am. Soc. C. E., December, 1929, Papers and Discussions, p. 2651.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

WILLIAM WALLACE BRIER, M. Am. Soc. C. E.*

DIED DECEMBER 28, 1928.

William Wallace Brier, the son of the Rev. William Wallace Brier, a Presbyterian home missionary, and Elizabeth Ann (Naylor) Brier, was born near Centerville, Calif., on August 7, 1858. He was a grandson of Lieutenant Benjamin Lodge, of the Pennsylvania Continental Line, one of the original members of the Society of the Cincinnati. His father was of Scotch descent and his mother of English Quaker ancestry, her family having settled in Pennsylvania after buying large tracts of land from William Penn in 1682.

Mr. Brier attended the public school near his father's farm, and, under his tutorship, prepared for the University of California, from which he was graduated in 1882 with the Degree of Bachelor of Philosophy in Civil Engineering.

In 1882 and 1883, Mr. Brier was employed on maintenance of way and water supply work as an Assistant to the Division Engineer of the Galveston, Harrisburg and San Antonio Railway Company, a subsidiary of the Southern Pacific Railroad.

From 1884 to 1890, he taught school in San Luis Obispo and Los Angeles Counties, California, and conducted a book business in San Francisco, Calif. He returned to engineering in 1891, and was in private practice until 1897, in which year he was appointed Civil Engineer of the Alameda Sugar Company, at Alvarado, Calif., and, later, of the Union Sugar Company, at Betteravia, Calif., in charge of railway, irrigation, drainage, and reclamation work.

Mr. Brier remained in these positions until March, 1901, at which time he became Chief Engineer of the E. B. and A. L. Stone Company, General Contractors, at San Francisco. During his connection with this firm, which continued until the end of 1905, he superintended the construction of the plant of the Standard Portland Cement Company at Napa Junction, Calif., the erection of the Los Angeles and Salt Lake Railroad Company's concrete bridge across the Santa Ana River, in California, and also had charge of numerous other contracts which the firm was executing.

While he was superintending construction, Mr. Brier had made a study of contractors' methods and, after leaving the Stone Company, he decided to make use of his acquired experience. In March, 1906, he organized the Occidental Construction Company, of Los Angeles, Calif., which specialized in railroad construction, and of which he was President and Engineer. In 1917,

* Memoir prepared by the following Committee of the San Francisco Section: Bernard Benfield and Jerome Newman, Members, Am. Soc. C. E.

he founded the Western Reinforced Concrete Pipe Company, of Los Angeles, which was engaged in the design, manufacture, and installation of this class of pipe, and of which he was also President and Engineer. Early in 1923, he disposed of his interests in Los Angeles and moved to San Francisco, where he maintained an office as a Consulting Engineer until a few months before his death.

Mr. Brier was married on March 27, 1889, to Helen Maria Blake who, with four children, William Wallace III, Edward Blake, Helen Naylor, and Isabel Presbrey Brier, M. D., and two sisters, Mrs. Mary Brier Moores and Mrs. Carrie Brier Schorr, survives him.

In all the relations of life, as a dutiful son, husband, and father, as a friend, engineer, contractor, and citizen, William Wallace Brier was a modest, kindly, sterling character. Firm in his beliefs, yet wholly tolerant and considerate of the views of others; loyal to those whom he served and appreciative of those who served under him; public-spirited, and deeply interested in all matters affecting the Commonwealth; faithful to every promise and every obligation; he gave freely and efficiently of the best that was in him in everything that he undertook. The world can ill afford to lose a man such as he was; his passing has left a deep sense of loss in the hearts and memories of those who were privileged to be associated with him in any phase of his long and active career.

Mr. Brier was a member of the Commonwealth Club of California, and the Engineers Club of San Francisco, the Astronomical Society of the Pacific, the Seismological Society of America, the American Association of Engineers, and the American Association for the Advancement of Science. He was also a member of the Masonic Order and of Phi Gamma Delta Fraternity.

Mr. Brier was elected a Member of the American Society of Civil Engineers on October 21, 1924.

JAMES FRANCIS CASE, M. Am. Soc. C. E.*

DIED DECEMBER 14, 1929.

James Francis Case was born at Columbus, Wis., on September 22, 1868, the son of the Rev. George Wilkinson Case and Nina (Nash) Case.

He was graduated from the University of Wisconsin in 1890. There followed a few years of railroad work in the Middle West; then came the Spanish-American War when he left Oregon as the Captain of a Company of Militia—was made a Major for gallantry and distinguished service in the Philippines; served as a City Engineer of Manila; and, in 1908, was made Director of Public Works. During this period he did important work in the construction of harbors, roads, water-works, and sewers. He became proficient in the Spanish language and, later, a master of French, both of which were to be very helpful to him.

* Memoir prepared by Paul G. Brown, M. Am. Soc. C. E.

Major Case then became the Havana Representative of the Cuban Engineering and Contracting Company and, as its Vice-President, carried out the largest sanitary project the world had yet seen, building several hundred miles of sewers and drains and a very novel turbo-electric pumping station for that city.

In 1916 he joined the staff of the American International Corporation. He reported upon engineering projects of magnitude in Spain, Greece, Mexico, and South America, and also served as contact between his Company and the United States Government in the vast construction enterprises carried out by that Company during the World War.

For Ulen and Company Major Case negotiated many contracts in foreign countries, notably that for the construction of the water-works in Athens, Greece.

In 1928 he was appointed Paris Representative of Stone and Webster, Incorporated, which position he held at the time of his death. Taken ill with pneumonia while on a business trip in this country, he died in New York, N. Y., of heart failure, on December 14, 1929. He is survived by his widow, Helen (Smith) Case.

Born in a small town in the Middle West, this son of religious parents, with but little help, save his own indomitable will-power, secured for himself an education, and, later made for himself fame as an engineer, a reputation for kindness to his fellowmen, and an acquaintanceship which circled the globe. He was loved by bootblacks and bank presidents and was the friend of two Presidents of the United States, the Presidents of many Central and South American countries, and of several of the crowned heads of Europe.

Major Case was chosen by the League of Nations to report on the transportation system of Poland. In 1918, he headed a delegation of American engineers that attended a Reconstruction Congress in France, at the invitation of the French Society of Civil Engineers.

In 1929 he was awarded the James Laurie Prize by the Society for his paper "The Ancient Roman Aqueduct at Athens," which has been published* and is an outstanding contribution to engineering literature.

Major Case was a member of many clubs and societies, among which were: Western Society of Engineers, The Engineers' Club of New York, American Club of Havana, Havana Country Club, Havana Yacht Club, Vice-President, Societa Italo American di Studi E. Lavori Publicci, Member d'Honneur, Société des Ingénieurs de France, Bankers Club of America, Sleepy Hollow Country Club, Army and Navy Club of Washington, D. C., and the Four Square Club, New York.

His life was a busy and a useful one, yet he was fond of sports and was helpful to his clubs. He served as a Governor of The Engineers' Club of New York for several years.

Major Case was elected a Member of the American Society of Civil Engineers on January 6, 1904.

* *Transactions*, Am. Soc. C. E., Vol. 91 (1927), p. 281.

EUGENE FRANK DELERY, M. Am. Soc. C. E.*

DIED NOVEMBER 24, 1929.

Eugene Frank Deléry, the son of Frank F. and Cora (Hall) Deléry was born in New Orleans, La., on November 26, 1877. Educated in New Orleans at Farde's Private School, and, later, at Tulane High School and Tulane University, Mr. Deléry was graduated from the latter in Civil Engineering in 1899 and in Mechanical Engineering in 1900.

From July to September, 1899, Mr. Deléry served as Rodman and Computer with the Mississippi River Commission on levee surveys and erection; during April and May, 1901, on design and irrigation plant and boiler settings, for A. M. Lockett and Company, New Orleans; and from May to December, 1901, as Draftsman for the Johnson Iron Works, New Orleans, on steel hull construction of the Southern Pacific tugs, *El Vivo* and *El Listo*, boiler piping, and general machinery design.

From December, 1901, to September, 1903, Mr. Deléry was engaged in private design work, chiefly for the following firms: The Shakespeare Iron Works, the John N. Murphy Iron Works, and with Frank Paul Barber, New Orleans. From September, 1903, to June, 1904, he served as Manager of the St. Louis Rice Mill. In July, 1904, he entered into private design practice and general machinery design. From January, 1905, to August, 1908, he was Surveyor and Construction Engineer at the U. S. Naval Station, New Orleans.

From 1908 to the date of his death, Mr. Deléry served as Assistant Engineer of the Sewerage and Water Board of New Orleans. His most important piece of work done in this connection was in the capacity of Designing Engineer on the Purification Plant Extension.

His contemporaneous private practice covered irrigation plant design, settling tanks for settling out by-products, and miscellaneous machinery design. He had acted as Consulting Engineer for the architectural firm of Emile Weil, Incorporated, on the construction of the new Saenger Theatre and the Tulane University Stadium. At the time of his death he was associated with the J. F. Coleman Engineering Company on the design of filter plants. He was also associated as Consulting Engineer for A. Merrick Blamphin, Assoc. M. Am. Soc. C. E., on drainage work in St. Bernard Parish, Louisiana, and with Henry A. Mentz and Company, Consulting Engineers, of Hammond, La., on the design of plants for water filtration.

Mr. Deléry's mechanical and engineering ability resulted in the invention of the rotary flow pump and impact strainer system. He also had patents on the following appliances: Axial flow pump, the hydraulic thrust bearing, and a machine for forming the depressed orifices in the impact strainer tubes, with other patents on hydraulic appliances pending in the Patent Office.

The impact system of filter underdrains, of which he was the inventor, has proved very successful and is in use in the 72 000 000-gal. addition to the New Orleans Filtration Plant, and has been installed in the 24 000 000-gal. addi-

* Memoir prepared by Henry A. Mentz, President, Henry A. Mentz, Inc., Hammond, La.

tion to the Tulsa, Okla., Filtration Plant. They have also been installed at Franklin, Donaldsonville, Monroe, and Lafayette, La., and Wemoka, Okla., and at the time of Mr. Deléry's death, were being considered for several large cities.

Mr. Deléry was a member of the American Society of Mechanical Engineers, and the Louisiana Engineering Society. He was also a devout member of the Roman Catholic Church, and of the Society of the Blessed Virgin of the Church of the Immaculate Conception, New Orleans.

Stricken in the prime of life, he died on November 24, 1929, of a cerebral hemorrhage, due to high blood pressure and heart trouble, in the chapel of the Ursuline Convent, where he had stopped for a moment in prayer.

On July 9, 1918, Mr. Deléry was married to Edna Marie Fuselier. He is survived by his widow, and two small children, R. de la Claire and E. Marie Yvonne, also by two brothers, Clarence H. and Frank B. Deléry, and five sisters, the Misses Caro, Edna, and Cora Deléry, and Mrs. C. A. Shaw and Mrs. Freret.

A man of charming personality and lovable character, Mr. Deléry was admired by all who came in contact with him, for his great ability as an engineer, and for his many endearing qualities as a man.

His professional work was marked by a high degree of integrity. His death is deeply deplored by all his associates, by whom he was held in the highest esteem and who hold his memory in affectionate regard.

Mr. Deléry was elected an Associate Member of the American Society of Civil Engineers on May 7, 1913, and a Member on March 16, 1925.

HARRY FOOTE HODGES, M. Am. Soc. C. E.*

DIED SEPTEMBER 24, 1929.

Harry Foote Hodges was born in Boston, Mass., on February 25, 1860, the son of Edward Fuller and Anne Frances (Hammatt) Hodges. Both his parents belonged to families well known and respected. His father, Edward Fuller Hodges, was one of the most prominent and successful members of the Suffolk County Bar. Harry Foote Hodges traced his descent directly from William Hodges, the founder of the Taunton Branch of the family, who emigrated from England to Taunton, Mass. and died there in 1654. Others of his paternal grandparents were George Hodges who served with distinction in the French and Indian War, and Silas Hodges, a Surgeon in the Continental Army and many times in personal attendance on General Washington.

As a boy, Harry Foote Hodges prepared for college at the Boston Latin School and the Adams Academy, at Quincy, Mass. He entered the United States Military Academy at West Point, N. Y., in 1877, and as a cadet he early began to show the qualities which were later to distinguish him. One of the youngest members of the graduating class of 1881, he stood fourth in

* Memoir prepared by Duncan Hodges, Esq., Lake Forest, Ill.

the Class. As a First Classman he was Cadet Lieutenant and Quartermaster. On being graduated, he received a commission as Additional Second Lieutenant in the Corps of Engineers of the Army.

After serving for four years at the Engineer School and as Adjutant of the Battalion of Engineers at Willets Point, N. Y., Lieutenant Hodges was assigned as Assistant to the District Engineer in charge of works on the Great Lakes, with headquarters at Detroit, Mich. He remained on this duty until 1888, principally engaged on the design of parts for the Poe Lock at the Sault Ste. Marie Canal, for which he also designed the steel lock-gates.

Lieutenant Hodges then returned to the U. S. Military Academy as Assistant Professor of Civil and Military Engineering. After this tour of duty he was appointed as Assistant to the late Col. Amos Stickney, Corps of Engineers, U. S. A., at Cincinnati, Ohio, on the improvement of the Ohio and tributary rivers. In 1893, he was promoted to the grade of Captain and placed in charge of improvements of the Upper Missouri and other rivers. This work included dike construction, snagging, and extensive surveys. On his relief from this detail, Captain Hodges served as a member of the Engineer Board, and originated the design of many features for mounting modern sea-coast guns.

At the outbreak of the Spanish War, he was appointed Lieutenant-Colonel and then Colonel of the 1st U. S. Volunteer Engineers, Porto Rican Expedition. During the war he remained in Porto Rico making roads and surveys and constructing defensive works, reservoirs, refrigerating plants, and bridges. Returning to the United States in 1899, he was placed in charge of river improvements at Cincinnati, until 1901, when he became Chief Engineer under General Wood, in the Department of Cuba, in charge of the works of the Port of Havana and other military and civil projects. On his return from Cuba, he was assigned to the Office of the Chief of Engineers in Washington, D. C. He was promoted to the grade of Major shortly after surrendering his commission as a Colonel of Volunteers.

In 1907, while Major Hodges was still on duty in the Office of the Chief of Engineers, the late George W. Goethals, Major-General, U. S. A., M. Am. Soc. C. E.—who had been appointed to succeed John F. Stevens, Past-President Am. Soc. C. E., as Chief Engineer of the Panama Canal—expressed his desire to the President to have an officer of the Canal Commission who was thoroughly familiar with lock structures and competent to design them. He suggested Major Hodges, explaining to the President his connection with the Sault Ste. Marie Canal and the design of the gates for the Poe Lock. However, the late Gen. Alexander MacKenzie, U. S. A. (*Retired*), Hon. M. Am. Soc. C. E., then Chief of Engineers, objected to the relief of Major Hodges on the ground that his departure would cripple the work of the Department. Shortly after, however, Major Hodges was assigned as General Purchasing Officer for the Isthmian Canal Commission, with headquarters in Washington. As such he supervised the purchase of immense quantities of materials required for the construction of the Panama Canal.

In August, 1907, President Roosevelt appointed Lieutenant-Colonel Hodges a member of the Panama Canal Commission. On the Commission he ranked next to General (then Colonel) Goethals, and was Acting Chairman in the latter's absences. As Assistant Chief Engineer of Canal Construction, he was given general supervision of the design and construction of the locks, dams, and control works. A number of the most valuable features of the Canal are the direct results of his engineering skill.

In Joseph Bucklin Bishop's book entitled "The Panama Gateway", there appears the following paragraph in which General Goethals estimates Colonel Hodges' services:

"He took over the designing work for the Panama Canal at a time when definite plans had to be adopted and the work carried to completion. Comprised in that work were designs for the dams, locks, gates, spillways, valves, operating machinery, hydro-electric station, and aids to navigation. He was placed in charge subsequently of the erection of the gates and the installation of valves and operating machinery. Charged with the solution of the most important engineering problems of the canal, it can be said of him truthfully *that the canal could not have been built without him.*"

It must not be supposed that Colonel Hodges completed the design and construction of the locks and dams of the Panama Canal without much technical criticism by engineers in the United States. During construction days on the Canal; it was often heard that certain of the designs of the locks were faulty. It was even rumored that the methods of suspending the 730-ton lock-gates were inadequate to the loads imposed. In view of the magnitude and uniqueness of the task assigned to Colonel Hodges, it is not surprising that such criticism existed. Nearly eighteen years have passed since the first gate was swung into position. Constant operation of the lock machinery without essential modification has proved its soundness beyond all doubt. The fact that able engineers at one time criticized the design now shows how difficult the project was technically, and how great the feat accomplished.

Shortly after the first steamer passed through the Canal on August 15, 1914, Colonel Hodges returned to the United States. In March, 1915, he was promoted to the grade of Brigadier General of the Line of the Army and received the distinguished honor of the Thanks of Congress for his services. He remained in Washington in charge of the Washington Engineer District until May, 1915, when he assumed command of the North Atlantic Coast Artillery District, with headquarters at Fort Totten, N. Y.

In August, 1917, promoted to the grade of Major General (National Army), he assumed command of the 76th Division, Camp Devens, Massachusetts. The supervision of the building of the Cantonment and the organization and training of the Division were entrusted to him. On December 10, 1917, he was ordered overseas on an observation tour of the Allied Forces in France, returning in February, 1918. While in France, he was with the New Zealand Division, 2d British Army, in the Ypres Sector, and the 4th Division, French 2d Army, in the Avecourt Sector. On returning to the United States he again took command of the 76th Division. In July, 1918, he sailed with his Division for France, where he remained until after the

signing of the Armistice. Among his awards was the Distinguished Service Medal, with the following citation:

"For exceptionally meritorious and distinguished services in a position of great responsibility. As Commanding General, Camp Devens, Massachusetts, he displayed unusual administrative and executive ability, sound judgment and high professional skill. He established a model system of schools and training, organized and trained the 76th Division, and in addition thereto trained for overseas service more than 40 000 men of other units. His untiring energy, devotion to duty, coupled with other outstanding soldierly qualities, contributed markedly to the successful operations of the American Forces during the World War."

After the war, General Hodges commanded, successively, the 20th Division at Camp Sevier, South Carolina, Camp Travis, Texas, and the North Pacific Coast Artillery District, retiring in the grade of Major General on December 22, 1921, after more than forty years' continuous and conspicuous duty in the service of his country.

General Hodges possessed, to an unusual degree, all the qualities of the successful engineer, combining with high mental alertness a great power of concentration. He was able to deal successfully with a multitude of details without losing sight of the end to which he strived. He prepared himself painstakingly for each task assigned him. One of his foremost characteristics was his mental integrity; he could not bring himself to countenance either carelessnes or inaccuracy. A man of such energy and driving power, he required his subordinates to live up to the standard he set for himself. He contrived to accomplish this without nagging or undue pressure. Quiet and self-possessed, he never resorted to the tactics of the slave driver. By his own example he was able to gain and keep the respect and loyal support of those under him. In later years, when he held positions of high command, he never permitted himself to hide behind his rank; he faced all issues squarely as they were presented to him. He was exceedingly astute in grasping the details of plans submitted to him. In whatever capacity, or wherever he served, men soon learned that he quickly got to the bottom of any problem and, having determined all the facts to his satisfaction, took action promptly and efficiently.

After his retirement from active service, General Hodges made his home in Lake Forest, Ill. He devoted his time to reading, studying, and his favorite outdoor sports, shooting and golf. In September, 1926, he suffered the loss of his wife, Alma L'Hommedieu Reynolds, to whom he was married in December, 1887. The attachment between the two was such that it could not be supposed that he would long survive her. General Hodges died at his home in Lake Forest on September 24, 1929, and is survived by his daughters, Mrs. A. H. Acher and Mrs. G. L. Dickson, and his son, Duncan Hodges.

General Hodges' death brought many tributes from all parts of the United States showing the great respect and high regard in which he was held. Gen. Charles P. Summerall, U. S. A., Chief of Staff, wrote in part that:

"From the date of his appointment as Second Lieutenant in the Corps of Engineers until his retirement as a Major General more than forty years

later, General Hodges had undertaken the performance of every duty assigned him with characteristic zeal and energy. His successful accomplishments were only limited by the number and variety of the responsibilities entrusted to him. In his death, which is deeply regretted, the Army loses one of its most brilliant and successful officers."

General Hodges was elected a Member of the American Society of Civil Engineers on March 4, 1903.

CHARLES RAYMOND HUMPHREYS, M. Am. Soc. C. E.*

DIED JUNE 1, 1929.

Charles Raymond Humphreys was born at Wayside, Md., on July 14, 1881. He was the son of Charles Humphreys and Elizabeth (Hungerford) Humphreys, and a descendant of Daniel Humphreys, who came to the United States from England in 1682, and settled in Sussex County, Pennsylvania. His great-great-grandfather, Joshua Humphreys, designed and built the first fleet of American warships, including the frigate, *Constitution* (*Old Ironsides*), and was Chief Naval Constructor during the administrations of Presidents Washington and Adams.

Mr. Humphreys moved, with the family, to Wilmington, N. C., in 1893. His father was a Government Engineer and was transferred to this District at that time. He resumed his primary studies here with Professor Catlett's private classes, later going to Pantops Academy at Charlottesville, Va., where he completed his preparatory schooling. He then entered Rensselaer Polytechnic Institute, at Troy, N. Y., from which he was graduated with the degree of Civil Engineer in June, 1904. He was elected to membership in the Chi Phi Fraternity.

His first engineering work was during the summer vacations of 1902 and 1903, as Instrumentman with the United States Government at League Island Navy Yard at Philadelphia, Pa. After his graduation in June, 1904, and until January, 1905, he was with the Government forces on surveys and soundings of the Mississippi and Ohio Rivers.

From January, 1905, to January, 1907, Mr. Humphreys was connected with the Carolina Trucking and Development Company of Wilmington, in charge of surveys and the location of farm colonies in several Eastern Carolina Counties, and, later, he was Chief of Party on surveys and reports on water-power projects on the Pee Dee River. From January, 1907, to July, 1908, he was with the Waccamaw Land and Lumber Corporation, Bolton, N. C., engaged on title surveys, and railroad location and construction. From July, 1908, to May, 1911, he was City Engineer of Wilmington, and during the time he held this office he assisted in making an appraisal of the privately owned water and sewerage system, which the City bought and to which, under his supervision, extensive additions were made. While serving in this office he also co-operated with the North Carolina Geological and Economic Survey

* Memoir prepared by W. K. Allen, Civ. Engr., and Col. R. S. McClelland, Wilmington, N. C.

in making investigations and reports on the feasibility of developing the vast areas of overflowed and waste lands in the Coastal Plane Section of Eastern Carolina.

From May, 1911, to May, 1917, Mr. Humphreys conducted a general engineering business, with an office at Wilmington. During this time he established a broad field of practice, requiring the assistance of a number of engineers to carry on his work. He was a good organizer and directed parties in the different branches of the field. He was for a number of years an active member of the North Carolina Drainage Association, the object of which was the promotion and advancement of the reclamation of over-flowed and waste lands for agricultural purposes. He was largely instrumental in the organization of many of the most important drainage districts in the State, directing the surveying and mapping of the areas affected and designing systems of drainage canals that made it possible to return to agriculture many thousands of acres of erstwhile jungle lands, bettering health conditions, as well as enriching those sections which had heretofore been considered worthless, and a menace to good health. He also made surveys and reports on forestry conditions for a number of Eastern North Carolina Counties, and, again, in 1917, he was Chief of Party on investigations and surveys for the development of water power on the Pee Dee River, in the Piedmont Section of North Carolina, for the Carolina Light and Power Company. It was while he was engaged in this work that his career as a brilliant engineer and a useful citizen was interrupted by his entry into the service of his country in the World War with Germany.

Immediately after war was declared Mr. Humphreys offered his services, and was ordered to the Officers' Training Camp at Chattanooga, Tenn., and American University, Washington, D. C., for military training, being commissioned with the rank of Captain, Engineer Corps, on June 19, 1917, Captain Humphreys was ordered to duty with the 105th Engineers at Camp Sevier, South Carolina, where he served as Topographical Officer and in various other capacities, leaving the United States with the American Expeditionary Forces on May 27, 1918. While in France, Captain Humphreys acted as Water Supply Officer of the American 2d Corps, and had charge of the survey of the St. Quentin Canal and Tunnel from November 4 to 11, 1918. He participated in the following engagements: Ypres-Lys Offensive, August 19-September 5, 1918; and Somme Offensive, September 20-October 8, 1918, Defensive Sector. Captain Humphreys returned to the United States on May 20, 1919, and was honorably discharged at his request on June 5, 1919.

Immediately after his discharge, Captain Humphreys took an active part in securing options, examining titles, and mapping outlines of a proposed 75 000-acre Soldier-Sailor Home Colony, in Eastern North Carolina, a project then contemplated by the Government, to provide homes and employment to *ex*-service men. He devoted much of his time to this movement during the summer of 1919.

From September, 1919, to September, 1921, he was City Engineer of Whiteville, N. C., during which time he directed a two-year street-paving program and water and sewerage extensions. In October, 1921, he resumed practice

as a private engineer, with offices at Wilmington, and continued in this field until his health failed in the spring of 1928. During this time Captain Humphreys was in charge of road work for a number of counties in which modern roads were being built; he wrote plans and specifications and supervised the construction of this work and had a broad field of practice embracing all branches of the profession. His service and opinion on title work were sought by many corporations and holders of large areas of land over the State. He was again employed by the Waccamaw Land Corporation with which he was engaged in 1907.

Captain Humphreys had a pleasing personality and a genial disposition, which won him friends everywhere, and he was ever ready to assist a fellow man in need and give aid to any worthy cause. He was punctilious in his habits, and painstaking in the performance of his duties.

He was married at Wilmington, on November 22, 1910, to Lillian Kenly, who, with their four children, Charles Raymond, Jr., Lillian Kenly, Mary Elizabeth, and Nancy Clark, as well as his mother and two sisters, survives him.

Captain Humphreys was elected an Associate Member of the American Society of Civil Engineers on June 3, 1915, and a Member on January 16, 1928.

ARCHY MAGILL NELSON, M. Am. Soc. C. E.*

DIED JUNE 26, 1929.

Archy Magill Nelson was born at Green Mountain, Va., on November 1, 1862, the son of Archie M. and Eliza Price Nelson. He received his education at Washington and Lee University, Lexington, Va.

Mr. Nelson's early engineering experience was acquired in service with the Pennsylvania Railroad Company and on the Schuylkill Valley Railroad from 1882 to 1885, where he advanced rapidly from Axeman to Assistant Engineer in charge of construction and location. He remained with the Pennsylvania Railroad Company until 1890 in charge of heavy construction and difficult location work.

In succeeding years he was employed in the following positions. From 1890 to 1900, as Principal Assistant Engineer on the Kansas City Southern Railroad, having charge of location and construction of approximately 500 miles of that railway, including yard and terminal and division point layouts and facilities; from 1900 to 1908, with the Kansas City, Mexico and Orient Railroad Company, in charge of very heavy and difficult location in Old Mexico (the Sierra Madre Mountains), and of construction between Chihuahua, Mexico and the Pacific; from 1909 to 1911, with the Oregon Short Line Railway Company, in charge of a resurvey of about 2 500 miles of line, and, later, as Valuation Engineer on the Oregon Short Line and Southern Pacific Lines East of Sparks, Ore. From 1916 to 1919, he served as State Highway Engineer of Tennessee.

* Memoir prepared by M. P. Paret, M. Am. Soc. C. E.

Mr. Nelson was prohibited from active service in the World War on account of his age, despite the fact that his services were freely offered.

In 1919, following this period, he went to Memphis, Tenn., as County Engineer for Shelby County, acting as such until the fall of 1926. In addition to the opening, renewal, maintenance, etc., of many miles of county highway, with accompanying bridges, culverts, etc., Mr. Nelson designed and built numerous plants for the storage of gasoline and the storage and treatment of oils and other ingredients used in the carpet treatment of highways. A noteworthy piece of work was an 150-ft. reinforced concrete bridge over Nonvonnah Creek on the Hernando Road.

In 1926, Mr. Nelson had planned to retire from active practice, but rather reluctantly consented to plan and build twin tunnels through Missionary Ridge, for Hamilton County, Tennessee. These tunnels were each more than 1 000 ft. long, and of concrete construction. They were built for highway purposes and to develop suburban Chattanooga, and to connect that city more directly with Atlanta, Ga. The cost of the tunnels was approximately $500 000. Mr. Nelson's death occurred just before the finishing touches were put on the work.

In 1909, he was married to Lucy Beasley, of Murfreesboro, Tenn., who survives him.

A member of the Protestant Episcopal Church he was much interested in later years in church work in Memphis. In his life and work he was intensely practical, his engineering experience and knowledge being largely acquired in the "University of Hard-knocks". He had an uncanny ability to meet emergencies successfully.

He was a devoted husband and a loyal friend, always considerate of and highly respected by his associates and employees.

Mr. Nelson was elected a Member of the American Society of Civil Engineers on October 4, 1910.

ARTHUR CHARLES SANDSTROM, M. Am. Soc. C. E.*

DIED AUGUST 4, 1929.

Arthur Charles Sandstrom was born on April 26, 1888, at Roswell, N. Mex., the son of Joachim Charles Sandstrom and Jacobina Elsa (Funnemark) Sandstrom. Although a fourth generation American, he was of absolutely pure Norwegian strain, his great-grandparents having left Norway to settle in the United States in the early part of the Nineteenth Century.

The story of this remarkable man is one of stern courage and strenuous effort. On the death of his mother, his sole surviving parent, he, at the age of 13, found himself alone face to face with the problems of life. He had to earn his own living, support and educate himself, his three younger brothers, and a sister, as best he could.

In 1906, when 18 years of age, Mr. Sandstrom began his engineering career as Surveyor's Assistant in the employ of the Southern Pacific Railway Com-

* Memoir prepared by Robert W. Hornsby, M. Am. Soc. C. E.

pany in Central Oregon, which position he retained until the end of 1907. Subsequently, he was engaged as Surveyor and Draftsman on road construction and land surveys in the same State, studying assiduously the while at night and in his leisure through the International Correspondence Schools.

From May, 1908, to September, 1909, he was engaged as Levelman, Transitman, and Chief of Party on land sub-division, extensive topographical surveys, and railway location and construction for the United Railways Company, Portland, Ore.

From September, 1909, until May, 1910, he studied engineering at the Oregon Agricultural College, and, during the Christmas vacation, was Chief of Party on railway location for the United Railways Company. Later, until September, 1910, he worked as Chief of Survey, Draftsman, and Estimator for the same Company.

From October, 1910, until May, 1914, Mr. Sandstrom was both student and Assistant Instructor of Civil Engineering at Leland Stanford Junior University, California. During the summer vacations he was engaged on railway and hydro-electric studies in the Cascade Mountains, in Oregon, in the various capacities of Draftsman, Instrumentman, Chief of Party, Estimator, and Hydrographer. From June, 1914, he worked with the Standard Oil Company on the construction of oil tanks, laying pipe lines, and testing machinery.

He was appointed Resident Engineer in October, 1914, on the location and construction of twenty-five miles of highway which he finished in two years (July, 1916). He also did special work for the Spring Valley Water Company, of San Francisco, Calif., in the calibration of current meters, besides designing and constructing an irrigation system. Subsequently, he held the post of Inspector of Sewerage and Water Supply and other miscellaneous work for the City of Palo Alto, Calif. In this year, 1916, he was graduated as Civil Engineer from Stanford University.

South America now offered a wider field for his energies, and in July, 1916, Mr. Sandstrom entered the service of the Braden Copper Company in Chile, as Locating and Preliminary Design Engineer and Estimator for three large hydro-electric projects. He was Engineer-in-Charge over all work at the Pangal Plant (15 000 kw.) for one year, carrying out the construction of roads, housing, excavation of aqueduct, which included fifteen tunnels, and all the accessories of a great establishment. Then, successively, he was for one year, Assistant to the Construction Engineer in special hydraulic studies; in charge of the Materials Department, including requisitioning, tracing shipments, etc., to the extent of $10 000 000 (gold) worth of plant. As is usual in all mining work, his duties were of a most varied nature. He looked after the equipment and supplies; for four months he was Superintendent of Construction (and Manufacture) of 12 km. of 80-in. wood-stave piping (mastic lining), and an 8-mile timber tailings flume; completion of dwellings; operation of the aqueduct for the hydro-electric plant; transport of 15 000 tons of material over difficult mountain roads; and repair of hydraulic works destroyed in storms.

In November, 1919, Mr. Sandstrom transferred his services to the Andes Copper Company at Potrerillos, Chile, as Hydraulic Engineer in direct charge

of surveys, designs, and estimates of a 65-km. wood-stave pipe line in the High Andes (La Ola Pipe Line), including the partial excavation of several long hand-driven tunnels. He also made studies of possible hydro-electric plants in the same locality, surveys for a 90-km. railway and aerial tramway at an elevation of 17 000 ft. He was likewise Assistant Superintendent of Construction on preliminary work for large copper reduction plants.

In February, 1920, the Compania Chilena de Electricidad secured his services and Mr. Sandstrom was put in direct charge of the construction of a hydro-electric plant, "Maitenes", and the revision of an already existing plant, "La Florida", totaling 43 375 kw., together with all their accessory works (8-km. aqueduct) which he finished; he also made studies and surveys for future hydro-electric plants on near-by streams. He remained with this Company until June, 1920, having meanwhile solved the difficult problem of eliminating the unusual quantity of sand and gravel carried by the supplying streams.

Mr. Sandstrom's professional services as hydro-electric expert were then requisitioned by the Whitehall Securities Corporation, of London, England, whither he was called to work on designs and estimates for several proposed hydro-electric plants for Chile (22 000 h.p.) from July, 1924, to January, 1925.

Returning to Chile, he assumed the position of Chief Engineer with the Compania Hidro-Electrica del Volcan (a subsidiary company of the Whitehall Securities Corporation), for which he studied several hydro-electrical projects, making final surveys, plans, and estimates for a 40 000 h.p. plant on the Rio Maipo, near Santiago, Chile. He spent five months in England and the United States, completing the plans, ordering construction plant, and making the final arrangements to execute the work (the "Queltehues" Plant).

From April, 1926, until the day of his death Mr. Sandstrom superintended the construction of the Queltehues Plant (Rio Maipo) as Chief Engineer in direct charge of the entire technical construction, and of the commercial phases of the work in Chile. This, his last work, was completed at the time of his death in all but a few minor details. It was particularly difficult, the plant being situated in the upper reaches of the Maipo near its confluence with the Rio Volcan 80 km. southeast of Santiago, and 14 000 ft. above sea level, in the roughest country. The work was extremely heavy, and occupied 2 400 men during approximately 2 years. The aqueduct was 12 km., 3 m., long, 5 166 m. of which was covered, and 2 162 m., open canal. It also included five tunnels with a total length of 3 km., 495 m. The service roadway was 23.5 km. long, with township power houses and proportionate accessories. It is, to date, the largest plant on the Pacific Coast of South America.

On Sunday, August 4, 1929, Mr. Sandstrom was killed by a fall of 65 m., while inspecting a portion of the work. He had been ill in Santiago, but, ever attentive to duty, he rose and accompanied a commission of the management to look over the plant. He was standing on the edge of a chasm leading to the intake, in order to observe better the accumulation of sand, a problem that was always troubling him; the earth gave way, and he was precipitated to the bottom of the chasm and killed instantly.

The news of his death struck Santiago society, both native and foreign, with consternation and grief. His funeral was one of the largest ever seen in the Capital, as if his death had been a National loss (for so, indeed, it was considered), more than 1 000 persons having attended. Such was the end of this great American Norseman.

Mr. Sandstrom was a man of most noble character. There is a trite saying that "there is no greater enemy than one of one's own profession"; but such could never be said of him. He was a born leader (not driver) of men, a just and kindly chief, and a true comrade; hence, he compelled respect and admiration from all with whom he came in contact.

He had a most striking personality, and, as Walt Whitman aptly puts it, "he convinced with his presence." Cast in an heroic mould, of gigantic stature and physique, he worthily represented that mighty race which changed the history of the world, ten centuries ago, and whose descendants to-day form the best elements of English-speaking nations all over the earth.

He was adored by his workmen (for many of whom he had risked his own life on repeated occasions), and by his assistants who looked upon him as upon a father. He handled everything down to the minutest detail in his work, details which others usually leave to their assistants. He was always ready and eager to listen to any suggestion, even from his lowest workman, and to adopt it, did he find it feasible.

In social life Mr. Sandstrom was retiring, and preferred his family and his home which was his Paradise. Although a quiet, proud man, yet he was the essence of kindliness and consideration for others. He took an interest in Freemasonry, and was a member of the American Lodge ("Huelen Lodge") at Santiago.

Mr. Sandstrom possessed all the qualities of a great engineer, and was looked upon as the future organizer of projects of vast proportions embracing the whole of the Andes Range. His death at the early age of 41 years is a serious blow to the Engineering Profession.

In 1920, he was married at São Paulo, Brazil, to Lena Richardson, a native of Manchester, England, who, with four children, survives him.

Mr. Sandstrom was elected an Associate Member of the American Society of Civil Engineers on May 31, 1916, and a Member on July 16, 1928.

LLOYD SCHWARTZ, M. Am. Soc. C. E.*

DIED NOVEMBER 7, 1929.

Lloyd Schwartz, the son of John G. and Martha Jane (O'Neil) Schwartz, was born on September 1, 1889, in Golden, Ill. His early education was obtained in the public schools of that town. He was graduated in June, 1911, from the University of Illinois with the degree of Bachelor of Science in Civil Engineering. While at college he was a member of the University baseball

* Memoir prepared by E. R. Knight, Assoc. M. Am. Soc. C. E.

team, playing an outfield position regularly. Later, during the second semester of 1913, Mr. Schwartz took post-graduate work in Structural Engineering at the University, and at the same time was an Instructor in Surveying.

Immediately after his graduation in 1911, Mr. Schwartz accepted employment with the Division of Highways of the State of Illinois, and except for the time spent in post-graduate work at the University of Illinois and in the United States Army during the World War, he remained with that organization until his death. His advancement was continuous and in July, 1919, he became District Engineer of the Ninth District, which includes the southernmost fourteen counties of the State with headquarters in Carbondale, Ill. In this position, he directed all State highway activities in the District, including design, construction, and maintenance, and also acted as Consultant in county and township work.

From June, 1918, to June, 1919, Mr. Schwartz was in the service of the United States as a Master Gunner in the 72d Regiment of the Coast Artillery Corps. His overseas service extended from August, 1918, to May, 1919.

He was a member of the Dyhrkopp Engineering Company, a partnership of three, which was formed in October, 1925. He served this Company as Consultant Engineer until its dissolution in 1927. A few months after the Company was formed, he applied for, and after an examination, received his license as a Structural Engineer.

Mr. Schwartz was active in many civic, fraternal, and social enterprises. He held membership in the Carbondale Rotary Club, the American Legion, the Benevolent and Protective Order of Elks, the Masonic Blue Lodge, the Chapter, the Commandery, and Shrine, the Jackson Country Club, the Midland Hills Country Club, and the Dog Tooth Bend Hunting Club.

Lloyd Schwartz was a clean and ardent sportsman with marked ability in many forms of athletics. However, his recreational activities indicated a preference for golf in the summer and hunting in the fall and winter; and it was while hunting ducks at the Dog Tooth Bend Hunting Club on the Mississippi River that he met his death. Late in the afternoon of November 7, 1929, he had shot a duck which fell into the river a short distance from the blind. In attempting to retrieve it, he waded off a shelf in the river bed into deep water, and the weight of his hunting togs gave him no chance for his life.

Funeral services were held at his home in Carbondale, Ill., under the direction of the Knights Templar of Beauseant Commandery, after which interment ceremonies were completed in Golden, with the Masonic Blue Lodge of that town in charge.

He was married on February 14, 1920, to Lucinda A. Wesson, at Aurora, Ill., who survives him, together with three sisters, Mrs. Glen Cutforth, of Eldorado, Kans., Mrs. Laura E. Duff, of Cedarville, Wis., and Mrs. May Reitman, of Chicago, Ill., and two brothers, Earl Schwartz, of San Francisco, Calif., and Clyde Schwartz, of Quincy, Ill.

Mr. Schwartz was elected an Associate Member of the American Society of Civil Engineers on March 12, 1918, and a Member on March 15, 1926.

CHARLES ALFRED SHEPPARD, M. Am. Soc. C. E.*

DIED OCTOBER 18, 1928.

Charles Alfred Sheppard was born at Southampton, England, on February 12, 1866, the son of George and Ellen (Major) Sheppard. In 1870, the family came to the United States and settled at Beatrice, Nebr.

Mr. Sheppard began his engineering career by employment in minor capacities, on railroad location surveys and construction work during the great development of the West in the Eighties. At that time he was engaged in work for various railroads which have since become part of the Chicago, Burlington and Quincy Railroad System. In 1888, he devoted a year to special study at Fairfield College, Fairfield, Nebr., and, in 1889, became Assistant Engineer in charge of second-track construction for the Louisville and Nashville Railroad Company.

An extensive industrial development was started at Granite City, Ill., in 1892, and Mr. Sheppard was placed in charge of the field work, supervising the construction of the sewer system, water-works, streets, paving, etc. To a large extent, this undertaking proved to be the turning point in his career, as from that time on practically all his work was in connection with the growth of the St. Louis Industrial District on the east side of the Mississippi River in the construction of railroads, levees, sewers, drainage systems, and highways. This work grew to such an extent that, in 1900, he formed a partnership with Mr. W. H. Morgan, with offices at Edwardsville, Ill. This partnership continued until his death.

When the construction of the Chain of Rocks-Kingshighway Bridge across the Mississippi River was begun in the fall of 1927, Messrs. Sheppard and Morgan were retained to supervise the work on the east side of the river, and Mr. Sheppard devoted most of his time to this work until October, 1928, when he took a short vacation to visit a sister in Omaha, Nebr., who was ill. As he was preparing to return from this trip on October 18, his automobile was struck by a heavy truck and he was instantly killed.

Like many other engineers, Mr. Sheppard was very modest as to his ability. He was held in high esteem by all who knew him. One of his principal pleasures was derived from his membership in the choir of St. John's Methodist Episcopal Church of Edwardsville. His true character as a man cannot be better expressed than in quoting from a resolution prepared by the Official Board of that Church:

"He had profound and clear Christian convictions, and translated them into the practices of his daily life. All his conduct was a practical application of his religious principles. Recognizing that beliefs are individual, he did not attempt to impose his beliefs or rules of conduct on others, and could hold and express differences of opinion without giving or taking offense. Capacity for integrity, sound judgment, and industry, a talent for friendship, never failing good humor, are qualities he shared with many; few are as faithful in daily life to lofty spiritual ideals.

* Memoir prepared by Baxter L. Brown, M. Am. Soc. C. E., and W. H. Morgan, Esq., Edwardsville, Ill.

"The close of his life, like the setting sun, leaves to the world the glow of perfect day.

"Walk with him and keep unbroken
The bond which Nature gives,
Thinking that our remembrance, though unspoken,
May reach him where he lives."

In 1895, Mr. Sheppard was married to Olive Morgan, of Bostwick, Nebr., who died on June 25, 1927. Three children survive them: Leila, Robert, and Charles H. The latter has succeeded his father in the re-organized firm of Sheppard, Morgan and Schwab, with offices at Edwardsville and Alton, Ill.

Mr. Sheppard was elected a Member of the American Society of Civil Engineers on November 30, 1909.

TIMOTHY SIDNEY WHITE, M. Am. Soc. C. E.*

DIED APRIL 15, 1928.

Timothy Sidney White was born in New Brighton, Pa., on April 3, 1852. His parents, Timothy Balderston and Olive (Howland) White, were Quakers. He spent his early life in New Brighton, where he attended a local public school. From there he went to Cornell University, at Ithaca, N. Y., from which he obtained the degree of Bachelor of Science in Civil Engineering in the Class of 1873.

In 1835, or thereabouts, Mr. White's father had established a contracting business in New Brighton, specializing largely in the design and construction of masonry, timber, and steel bridges. This, it is thought, was the oldest company of its kind in Western Pennsylvania. It eventually grew into the Penn Bridge Company of Beaver Falls, Pa., which was incorporated in the early Eighties. Mr. White became Chief Engineer and eventually Vice-President and Chief Engineer, remaining in this dual capacity for about thirty-nine years. He retired from active business in 1924.

During this period the Bridge Company, under his engineering direction, grew rapidly. A large number of highway and railroad bridges throughout the eastern part of the United States were designed and built, all of which construction was done under Mr. White's direction as Chief Engineer. This work was highly diversified and included, not only bridges and buildings, but a great deal of specialized construction for the United States Government and various State, county, and city governments, and for many corporations as well. Among the important steel bridges built by the Penn Bridge Company are the four suspension bridges over the Ohio, at Rochester, East Liverpool, and Steubenville, Ohio.

Mr. White's professional life was identified with the development of the all-metal bridge from the small ones of wrought iron to the large modern bridges of high-tension steel. He was a student of engineering and deeply interested in the development of the steel bridge in general and especially in its details as they were related to facilities of manufacture. Under his

* Memoir prepared by Walter J. Douglas, M. Am. Soc. C. E.

direction as Chief Engineer, and that of his brother, Mr. S. P. White, as Business Executive, the Penn Bridge Company successfully undertook many important structures; some of them, such as the Anacostia Bridge and the Piney Branch Bridge in the District of Columbia, were largely masonry.

His work in structural engineering was nationally known, and he was highly regarded by the profession of bridge engineers throughout the country. He was a careful, conscientious, and most thorough engineer, and a student in the field to which he devoted his professional life.

Mr. White was a member of the Engineering Society of Western Pennsylvania, the American Society of Social and Political Science, and a Trustee and President of the Young Men's Christian Association at New Brighton. His clubs were the Duquesne Club of Pittsburgh, Pa., and Old Pueblo, of Tucson, Ariz.

He was an ardent Churchman, an active worker in the Protestant Episcopal Church, and prominent in the Diocese of Pittsburgh.

On June 8, 1876, he was married to Annie Augusta Appleton. He is survived by his widow and one son, Samuel A. White, of Beaver Falls, Pa.

Mr. White was elected a Member of the American Society of Civil Engineers on April 3, 1889.

BERTRAND DON BARKER, Assoc. M. Am. Soc. C. E.*

DIED NOVEMBER 7, 1929.

Bertrand Don Barker, the son of Don Barker and Adelia Barker, was born on June 17, 1881, at Poultney, Vt. His father was engaged in the operation of State quarries. The boy grew up in New England, attending the local schools. In 1903, he received the degree of Bachelor of Science in Civil Engineering from Norwich University, at Northfield, Vt.

Immediately after his graduation, Mr. Barker entered the service of the United States Coast and Geodetic Survey where his ability and energy brought him advancement. By July, 1905, he was Executive Officer of the U. S. S. *Hydrographer*. He served in this capacity on the *Hydrographer* and the *McArthur* until January, 1907, and in other capacities until May, 1907, when he resigned from the Service.

Mr. Barker next became connected with George W. Jackson, Incorporated, of Chicago, Ill., and New York, N. Y., as Engineer and General Foreman and Superintendent of tunnel construction. From January to August, 1910, he was Superintendent of Shaft No. 1 of the Washington Street Tunnel, Chicago, and from August, 1910, to February, 1912, General Superintendent of Shaft No. 1 of the Yonkers Pressure Tunnel on the Catskill Aqueduct.

In June, 1912, Mr. Barker became associated with George A. Quinlan, M. Am. Soc. C. E., Contracting Engineer of Chicago. Early in 1914, Mr. Quinlan was appointed County Superintendent of Highways of Cook County, Illinois, under the newly enacted Road Law. On assuming this position he took Mr. Barker with him as Chief Engineer.

* Memoir prepared by C. C. Wiley, M. Am. Soc. C. E.

When the United States entered the World War, Mr. Quinlan went into the Army, and Mr. Barker assumed temporary charge of the County Highway Department. In this capacity, throughout the period of the war, he rendered invaluable, if unrecognized service, to his country by developing and maintaining highway transportation facilities in the great industrial district about Chicago. On the return of Major Quinlan from the Army Mr. Barker was again able to devote his entire time to the engineering work of the Department. With the impetus given to road building by the war, and with funds available from both County and State Highway bond issues, Mr. Barker found plenty to do.

In 1925, with three of his friends, he organized the firm of Barker, Flavin, Sheets, and Wallace, Incorporated, Engineers, with offices in Chicago. Such time as he could spare from his public duties, he devoted to this firm of which he was President at the time of his death.

He was married to Mabel Gibbs, on January 18, 1905, at Chicago. He is survived by his widow and only daughter, Mary Ciel, and by his sisters, Mrs. Alice Jones and Mrs. Allyne Walker.

Despite the strenuous activities of his County Highway Office Mr. Barker always took an active interest in the affairs of the Society. Like many other men who are busy he postponed filing application for transfer to the grade of Member, although the nature of his work and the part he took in it would undoubtedly have entitled him to this honor.

As an engineer, Mr. Barker was capable, far-seeing, resourceful, energetic, and skillful. The development of the highway system in the metropolitan area around Chicago owes much to him. As a man, he possessed a brusque but delightful personality. His wide interest in things, his keen mind, and his ready sense of humor, made him liked by all, and he is mourned by his many friends and associates.

On the night of November 7, 1929, Mr. Barker was killed while on his way home from a meeting relating to highway affairs in one of the suburban villages, being struck by a switch engine at the crossing of the Indiana Harbor Belt Railway and West 74th Street, Chicago.

He was particularly active in securing separation of grades between railroads and highways wherever possible in the County. At the time of his death he was presenting the County's case before the State Utilities Commission for separation of grade on the particular crossing at which he was killed.

Mr. Barker was elected an Associate Member of the American Society of Civil Engineers on September 3, 1913.

CHARLES DIX McARTHUR, Assoc. M. Am. Soc. C. E.*

DIED NOVEMBER 28, 1929.

Charles Dix McArthur was born in Plattsburgh, a small town near Springfield, Ohio, on August 23, 1870. His father, Smith McArthur, of Scotch ancestry, was a grandson of Duncan McArthur, Governor of Ohio. His

* Memoir prepared by William Mayo Venable, M. Am. Soc. C. E.

mother, Phoebe (Judy) McArthur, was of Swiss lineage. His early education was in the public schools in Plattsburgh and New Carlisle, Ohio, and, later, he had an opportunity to attend Antioch College for two years, but the necessity of earning his own living prevented his graduation.

In 1896, while working for the Eastman Kodak Company of Rochester, N. Y., Mr. McArthur took advantage of the night course in machine design at the Mechanics Institute in that city from which he received a diploma in June, 1900. From 1897 until 1901 he was also Instructor in Mechanical Drawing at the Institute. In August, 1899, and during the year following, he was engaged in designing metal working machinery for the Gleason Tool Company. He resigned this position, however, to enter the employ of the Buffalo, Rochester, and Pittsburgh Railway Company, for which he designed the mechanical equipment of the locomotive repair shops at Dubois, Pa., and also superintended the erection of the equipment of these shops. In 1903, Mr. McArthur went as Master Mechanic to the Adrian Blast Furnace, at Dubois, removing to New York City in September, 1903, to become City Manager of the heating and plumbing business of Howe and Bassett. He spent several years in the heating business, during which he both designed and installed heating equipment in various buildings, notably the Stuyvesant High School.

In January, 1908, Mr. McArthur designed and applied for a patent on a steel form for use in the construction of the Catskill Aqueduct. This led to his employment as Chief Engineer by the Blaw Collapsible Steel Centering Company of Pittsburgh, Pa., which, later, became the Blaw-Knox Company. He remained with this company for many years, except for a brief interlude during 1913 and 1914 when he was employed by Stewart and Fauguier in the construction, in from 30 to 70 ft. of water, of the quay walls of the first unit of the Halifax Ocean Terminals for the Intercolonial Railway Company of Canada; he designed the forms for this construction work. While he was with the Blaw-Knox Company, Mr. McArthur took out more than twenty patents relating to steel forms for the construction of aqueducts, railway, and other tunnels, subways, retaining walls, and similar structures. He was a familiar and highly regarded figure wherever important concrete works were being designed or constructed. During most of these years Mr. McArthur lived in Pittsburgh, but he represented the Company for a time in London, England, and also in California.

In 1928, he resigned from the Blaw-Knox Company for the purpose of devoting his entire time to the development and introduction of new woodworking machines which he had invented, and on January 2, 1929, the McArthur Company was incorporated with its office in Dayton, Ohio, for the purpose of manufacturing "undercut" boring machines, "metal dowls", and other patented specialties. This Company had just been brought to a profitable status when on Thanksgiving Day, November 28, 1929, while on a pleasure drive to dine in the country, he died quite suddenly and unexpectedly.

Mr. McArthur was always greatly interested in new engineering ventures and kept himself informed as to the latest developments in the Engineering Profession. He possessed a strong and forceful character, and his work in

his chosen profession was well done. He was loved and respected for his faithfulness, loyalty, and honesty by all with whom he came in contact. He loved music, books, flowers, and little children, the simple life, and the beauty of Nature. He liked to shape things with his own hands, was a finished workman in wood and metal, and adorned his home with cabinet work and carvings of his own making.

He is survived by his wife (*née* Therese M. Ridenour) and a son, Arthur, as well as a son, Duncan, by his first wife (*née* Louise Middledorf), of California. He is also survived by five sisters and two brothers.

He was a member of the Protestant Episcopal Church of the Redeemer in Pittsburgh, Davage Lodge (Masonic), Pittsburgh, the American Association for the Advancement of Science, the American Association of Engineers, and the Engineers' Club of Dayton.

Mr. McArthur was elected an Associate Member of the American Society of Civil Engineers on January 17, 1916.

ALBERT EDWARD PADDOCK, Assoc. M. Am. Soc. C. E.*

DIED APRIL 20, 1929.

Albert Edward Paddock was born at Malone, N. Y., on April 15, 1884. After completing a public school education he entered Syracuse University, at Syracuse, N. Y. He was registered in the Engineering Department, where he completed the first two years of a four years' course. Owing to the death of his father before the completion of his second year at college, he left school, with characteristic unselfishness, to assume the responsibilities of an oldest son of a large family. While at Syracuse he had taken an active part in athletics as Captain of the Freshman Crew and as a member of the University football team. Actuated by a determination to be self-supporting, he accepted in 1906 an assignment as Foreman of Construction and Operation of Water-Works in Dawson, Yukon Territory, where he remained for two years. On returning to the United States, he was employed as a Mechanical Operator for the Northwestern Improvement Company at Cle Elum, Wash.

In November, 1911, Mr. Paddock joined the U. S. Reclamation Service and was assigned as Surveyman and as a Foreman of construction work on the Tieton Project in the State of Washington. He was soon advanced to Chief of Party and then to Engineer in Charge of Engineering and Construction on a Division of this Project.

His next assignment in the Reclamation Service was as Engineer in Charge of Construction on a Division of the Sunnyside Project in Washington, on the completion of which he was assigned to the position of Locating Engineer on the Okanogan Project. Subsequently, he became Assistant Tunnel Superintendent on one of the features of the Yakima Storage Project.

When the Yakima work was completed in August, 1913, Mr. Paddock was employed by the Southern Alberta Land Company as Superintendent of Con-

* Memoir prepared by H. N. Savage, M. Am. Soc. C. E.

struction on a large concrete diversion dam and canal head-works on the Bow River, in Alberta, Canada. He transferred from this work in September, 1914, to the U. S. Reclamation Service, North Division, and was assigned as Foreman in charge of concrete conduit, outlet tower, and spillway excavation and construction on the Sherburne Lakes Reservoir Dam of the Milk River Project, in Montana.

Mr. Paddock then was assigned to the Shoshone Project, Wyoming, as Assistant Tunnel Superintendent. In this capacity he was engaged on the enlargement of the outlet tunnel and installation of balanced gates outletting from the Shoshone Reservoir. On the completion of this tunnel he was again assigned to the work on the Sherburne Lakes Reservoir Dam, from which he resigned in 1916 to accept a position as Superintendent of Construction of H. G. Fenton, Contractor, on the repair and extensions of the Sweetwater Dam, near San Diego, Calif.

On July 3, 1917, Mr. Paddock entered the employ of the City of San Diego and was assigned as Field Engineer on the construction of the Lower Otay Dam, which work was being carried on by contract. When the project was taken over by the City of San Diego in November, 1918, for construction by municipal forces, Mr. Paddock was advanced to the position of Superinindent of Construction. On the completion of the Lower Otay Dam in 1919, he was transferred in the same capacity to the Barrett Dam, which was also being constructed with municipal forces by the City of San Diego.

Mr. Paddock's outstanding success as a superintendent on heavy construction brought him to the attention of the Utah Construction Company to the service of which he transferred in August, 1920, as Resident Construction Engineer and Superintendent of the Hetch Hetchy Dam which the Company had under contract.

He continued in the employ of the Utah Construction Company continuously from that time until his fatal accident, with the following principal assignments of contract work: Construction Engineer on the Freeman Masonry Weir across the Sacramento River, about 25 miles above Woodland, Calif.; from December, 1923, to February, 1924, Superintendent of Construction on excavation and embankment for roadbed, incident to double-tracking the main line of the Southern Pacific System in the vicinity of Truckee, Nev.; from February to December 1924, Superintendent of roadbed construction on the Natrone Cut-Off in Oregon-California, for the Southern Pacific System; from February, 1925, to October, 1926, Superintendent of Construction of the American Falls Dam across the Snake River in Idaho, an important feature of the Minnedoka Project of the U. S. Reclamation Service.

Before the completion of this work Mr. Paddock was also assigned, in October, 1926, as Superintendent of Construction for the Contractor on the Gibson Masonry Dam of the U. S. Reclamation Service, about 70 miles west of Great Falls, Mont. He also continued to direct the building of the American Falls Dam until its completion early in 1927. At the same time he carried on the construction of the Gibson Dam and continued in charge to the time of his death which occurred on April 20, 1929, while in the performance

of his duties as he, with customary aggressive responsibility, considered them to be.

The construction riggers at the Gibson Dam, in moving the concrete-carrying chutes, fouled them against the high concrete hoist towers. Mr. Paddock, arriving on the scene and sensing the conditions and consequent delay, characteristically jumped on top of the concrete bucket then at the base of the tower, and signaled the engine-man to hoist him to where the chute was caught, about 100 ft. above the base of the tower. One of the riggers who had been fixing lines higher up in the tower also had noticed that the chute was caught, and without signaling for the bucket, and unknown to the hoisting engineer on the ground, came down the hoist cable hand over hand to where the chute was caught. Thus, he was inside the tower with his hand presumably on the hoist cable when the concrete bucket, with Mr. Paddock standing on top of it, was being hoisted. The rigger lost his hold on the hoist rope and inside tower frame and fell down inside the tower, a distance of about 60 ft., landing on Mr. Paddock. Mr. Paddock was fatally injured and died within a few hours; the rigger, however, escaped with only a few broken bones.

Throughout Mr. Paddock's professional work he had exemplified executive qualifications of a very prominent type. He was outstanding among the multitude of construction foremen in the loyalty he displayed toward, and received from, his associates and subordinates. This was primarily in evidence in his aggressiveness in automatically responding personally to every apparent requirement to do whatever appeared to him necessary without waiting for others, thereby materially advancing the progress of all types of work under his responsible supervision, although he never discounted or interfered with the duty or work of his subordinates who were effectively carrying on.

Mr. W. H. Mattis, President and General Manager of the Utah Construction Company, writes of the loss sustained by his Company as:

"* * * immeasurable, as he was a vital part of the Company, and an exponent of its policies. * * * his unusually high place in our organization was due to his outstanding personal ability and character. He seemed to exemplify all the ideals of high-minded men; he had the confidence of his superiors, the affection of his men, and the respect of all with whom he dealt."

On September 14, 1920, Mr. Paddock was married to Mary G. Riveroll, in Los Angeles, Calif., who survives him. He is also survived by his Mother, two brothers, and a sister. He was a member of Delta Upsilon fraternity, a Scottish Rite Mason and a member of Al Bahr Temple, A. A. O. N. M. S. He was buried in San Diego, Calif.

Mr. Paddock was elected an Associate Member of the American Society of Civil Engineers on November 26, 1918.